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THE ENGINEER

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London Fire Brigade Equipment

A RESOLUTION, calling upon the Exchequer to make bigger grants to fire authorities, was passed by the annual conference of the London Labour Party last week-end. It was moved by Mr. A. J. Keyse, of the Fire Brigade Union, who stressed the need for improving London's fire stations and fire-fighting equipment. Some months ago, it may be recalled, the London County Council's Fire Brigade Committee asked the chief officer of the brigade to prepare a report on the work of the brigade since it returned to the Council's control in April, 1948. That survey was embodied in the report which the committee presented to the L.C.C. last July and showed that the brigade had then about fifty old appliances, which, in normal circumstances, would have been taken out of commission. Only two new major fire-fighting appliances had been obtained by the L.C.C. since April, 1948, but, in the light of improving production for the home market, an order for six diesel-engined pump escapes was placed in the middle of last year. At the same time, the report noted the research work on equipment, which was always in progress, and referred in particular to experiments for extinguishing fires by means of "water fog," in order to minimise damage by water. The report also mentioned that the average age of London's fire stations was about forty-seven years, though four stations were more than seventy years old. It was pointed out that many of the stations had been designed for horse-drawn appliances and were therefore now inadequate for modern requirements, even where they were satisfactorily sited. Owing to restrictions imposed by the Government's capital investment programme, the Home Office had been unable to authorise any new construction during the calendar years 1949 and 1950. Similar restrictions had made it impossible to overtake all the arrears of maintenance work at fire stations. But, the report added, as a result of negotiations with the Home Office, it was hoped that greater progress would now be made. The report noted that, in the year ended March 31, 1950, the London Fire Brigade was called upon to deal with 203 fires requiring the attendance of more than two pumps, compared with 149 fires in the preceding twelve months.

Institution of Mechanical Engineers

AT the annual general meeting of the Institution of Mechanical Engineers, held in London on Friday last, Mr. Arthur Clifford Hartley, C.B.E., B.Sc. (Eng.) was elected to the presidential chair. Mr. Hartley was educated at Hymers College, Hull, the Hull Municipal Technical Institute and the City and Guilds (Engineering) College, London. His works training was gained with Rose, Downs and Thompson, Ltd., Hull, to which company he went as an assistant after spending two years in the office of the chief docks engineer, North-Eastern Railway, Hull. In 1914 Mr. Hartley was appointed works superintendent and engineer of the Limmer and Trinidad Lake Asphalt Company, Ltd., a position which he relinquished two years later to join the Royal Flying Corps. For much of the three following years Mr. Hartley served in the Air Ministry on experimental work, which included the development of the Constantinesco gear for synchronising machine guns to fire between the propeller blades of aircraft. After the first world war, Mr. Hartley became a partner in the consulting firm of Maxted and Knott and was engaged on the design and erection of cement plants. He joined the Anglo-Iranian Oil Company, Ltd., in 1924, and a year later was appointed assistant manager of the engineering and supply departments. During the succeeding five years, Mr. Hartley went to Persia at different times to deputise for the assistant general manager (technical), and when in London he undertook the duties of chief engineer. He held the position of chief engineer of the Anglo-Iranian Oil Company, Ltd., until the end of last year, when he relinquished it to become the company's consultant. Mr. Hartley was released by his company early in the second world war to assist in the development and production of a stabilised automatic bomb-sight and, from April, 1942, he was engaged with the Ministry of Fuel and Power on the invention and laying of the "Pluto" cross-channel petrol pipelines. In addition, from October, 1942, until the end of the war, Mr. Hartley served as technical director of the Petroleum Warfare Department, dealing with the "Fido" fog clearance scheme and with flame weapon development. He was awarded the C.B.E. in 1944 and the United States Medal of Freedom in 1946. Mr. Hartley was elected an Associate Member of the Institution of Mechanical Engineers in 1916 and a Member in 1927. He has served on the council since 1940.

Financing British Shipbuilding

AT the end of last week an announcement was made about the formation of a new company, with a capital of £1,000,000, to help shipowners to finance replacements and new ship construction. The company is to be known as the Ship Mortgage Finance Company and the members of its board will include Sir Amos L. Ayre, chairman of the Shipbuilding Conference; Sir Philip d'Ambrumenil, chairman of Gardner Mountain and d'Ambrumenil; Mr. J. Ramsay Gebbie, president of the Shipbuilding Conference and managing director of William Doxford and Sons, Ltd.; Sir James Milne, director of Coast Lines, Ltd., and Lord Piercy, chairman of the Industrial and Commercial Finance Corporation. The intention of the company is to make medium-term loans on first mortgages of ships constructed in the United Kingdom and to raise money for the purpose by the issue of medium-term debentures or other securities. It is stated that loans during construction are not contemplated; they will be made only on completion of the ship and, as a rule, will be limited to 50 per cent of the cost or value of the vessel. The company says that, although loans to British shipowners are primarily in view, it is hoped to make loans to foreign owners on new ships completed in United Kingdom yards, if exchange control and other conditions permit. Hitherto, it is explained, British shipbuilders themselves have been the chief means of financing the construction of new ships by granting extended terms of payment. Rising costs of materials and wages and high taxation, however, have considerably reduced the scope for such financing by shipbuilders.

The Late Sir Holbrook Gaskell

WE record with regret the death of Sir Holbrook Gaskell, which occurred suddenly on Saturday last, March 31st, at his home, 52, Orchard Court, London, W.1. He was a director of Imperial Chemical Industries, Ltd., until his retirement in 1946. Sir Holbrook was born in 1878 at Frodsham, Cheshire, and was educated at Rugby and Trinity College, Cambridge, where he gained the Mechanical Science Tripos in 1900. After leaving Cambridge, Sir Holbrook was appointed assistant engineer to the United Alkali Company, Ltd., and in 1914 he was promoted to the position of chief engineer. He was elected to the board of the company in 1922 and became managing director four years later. The United Alkali Company, Ltd., was one of the undertakings which joined Imperial Chemical Industries, Ltd., and on the formation of the latter company, Sir Holbrook was appointed chairman of the delegate boards of the general chemical and lime groups. He was elected a director of I.C.I. in 1934 and served in that capacity for the next twelve years. Sir Holbrook's knighthood was conferred in 1942.

The Festival of Britain Ship "Campania"

PARTICULARS have now been issued of the visits to be made to various ports in this country by the Festival of Britain ship, "Campania." The vessel, a converted naval ferry carrier, will have the exhibition arranged in its hangar, which is 300ft long, 70ft wide and 20ft high. The first half of the display in the hangar will be similar to that in the upstream sequence of the South Bank Exhibition. In it the origins of the British Isles and the British people will be illustrated, together with the agricultural use of the land and the mineral wealth of the country. In the subsequent sections will be shown the materials of industry, the development of power, transport and communications, sea and shipping, British discoveries, the domestic side of British life, rural life, &c. On the flight deck of the vessel six lifeboats equipped with self-propelling gear will be carried for both safety and exhibition purposes. The "Campania" will visit the following ports: Southampton (May 4th to 14th), Dundee (May 18th to 26th), Newcastle (May 30th to June 16th), Hull (June 20th to 30th), Plymouth (July 5th to 14th), Bristol (July 18th to 28th), Cardiff (July 31st to August 11th), Belfast (August 15th to September 1st), Birkenhead (September 5th to 14th), and Glasgow (September 18th to October 6th). During the exhibition periods the vessel will be moored with her starboard side to the quay and visitors will gain access by twin gangways to a large shelter space aft, whence they will enter the hangar on the port side.

Industrial Reorganisation in the Ruhr

SOME details have been given this week about decisions arrived at jointly by the High Commission and the Federal Chancellor for West Germany on the reorganisation of the coal and steel industries of the Ruhr. It seems that there are now to be twenty-eight unit steel companies—the largest of them being Mannesmannroehren at Dortmund—with a combined annual capacity of approximately 2,000,000 tons. Only 16·5 per cent of Western Germany's coal production, however, is to be placed directly at the disposal of these iron and steel companies instead of the 25 per cent originally suggested. It is understood that collieries are to be allocated to twelve of the iron and steel units, though only nine, responsible for about 14·5 per cent of the coal production, have so far been named. Recommendations will be made later by the Federal Government about the other three collieries. It is estimated that no colliery will supply the steel company to which it is attached with more than three-quarters of the coal it needs. The Federal Chancellor has emphasised to the High Commission that the coal and steel industry as a whole must subsequently come under the direction of the high authority set up under the Schuman plan.

Fracture Under Combined Stress Creep Conditions of a 0·5 per cent Mo Steel*

By A. E. JOHNSON and N. E. FROST

Summary

PURE tension, pure torsion and combined stress creep tests have been made on a 0·5 per cent Mo steel at a temperature of 550 deg. Cent., to examine the validity of the Siegfried hypothesis of fracture under combined stress creep conditions, and to establish a criterion of fracture. It has been found that the results obtained cannot be explained upon the basis of the Siegfried criterion, and that the criterion of fracture is apparently the maximum principal stress. All creep curves examined had a form given by the general equation :

$$\text{Creep strain} = C[K_1 t + At^n] + Be^{K_2 t},$$

where t is time and K_1, A and B, K_2 and C are constants.

Introduction

While up to the present time considerable attention has been given to the short period fracture of metals at room temperature in relation to an imposed general stress system, little attention has been devoted to the corresponding problems at high temperatures, and in particular to that of the longer period fracture of metals at high temperatures under conditions of creep.

It is this latter problem with which the current article deals.

Consideration was given to this matter in a paper published in 1943 by W. Siegfried,[1] who dealt with the creep failure of metals as influenced by general stress systems, over ranges of temperature, both above and below the so-called "equicohesive temperature," defined as that temperature below which fracture in creep is purely transcrystalline, and above which it is intercrystalline, depending in each case upon the supposed relative strength of crystal and boundary material. He suggested that below the equicohesive temperature the period to fracture depended upon the maximum stress deviator portion of the imposed stress system, which component was regarded as causing actual crystal distortion, while above the equicohesive temperature the period depended upon the hydrostatic component of the stress system, regarded as causing the fracture of boundaries.

General experience suggests that Siegfried's proposition should be qualified, inasmuch as for any particular material and temperature, the fracture occurring may not be wholly transcrystalline or intercrystalline, but partly both.

In view of the obvious lack of explicit information on the matter, it was decided to carry out a series of tests under conditions of general stress on a material at such a temperature, and in such a range of applied stress that the normal tensile creep test gave rise to virtually entirely intercrystalline fracture. It was felt that if a pure torsion creep test was made in such a stress range, the Siegfried theory would be given support, if the test gave a completely transcrystalline fracture, since, of course, the hydrostatic stress in pure torsion is zero. His theory would appear also to suggest, in view of the assumed greater strength of the crystals at this temperature, that the fracture period of this test would be long compared with tensile tests at equivalent stress.

Further tests suggested themselves in view of the fact that for a given system of applied tensile (t) and torsion (s) stresses the principal stresses are

$$p_1,\ p_2 = t/2 \pm \tfrac{1}{2}\sqrt{t^2+4s^2},\quad p_3 = 0,$$

and the hydrostatic stress $\Sigma p_1/3$ has the same value $t/3$, whatever the value of s. Thus, if two such systems be chosen with the same value of t, and two considerable differing values of s, then in the temperature-stress range corresponding to intercrystalline fracture for pure tension, the two combined stress tests should fracture in identical periods, providing the fractures are entirely intercrystalline, and these periods should, of course, equal the fracture period in a tensile creep test having a stress of t imposed.

It was initially intended to include such tests as the above in the investigation and to extend the same should the course of the results indicate the necessity.

Outline of Investigation

A suitable material for this work was at hand in the form of a 0·5 per cent molybdenum steel,† which previous tests had shown to be liable to intercrystalline fracture at temperatures above 500 deg. Cent.

In the first place, a set of tensile creep tests at 550 deg. Cent. was made on solid specimens of the material, to determine a range of stress over which under pure tensile conditions fracture would be virtually intercrystalline.

Subsequently, a further series of tests under pure tension, pure torsion, and three combinations of tensile and torsion stress, was made on tubular specimens, the stresses being so chosen that the range of the "equivalent stress" (i.e., the octahedral stress proportional to $\sqrt{t^2+3s^2}$), remained of much the same order as the equivalent stresses of the range of tensile stresses giving virtually intercrystalline fracture.

Details of Material and Specimens Used

The 0·5 per cent molybdenum steel used was in the form of a casting 7in square and 17in long. The material was produced in an acid-lined induction furnace and used in the as-cast condition.

The percentage composition was as follows:

C	0·00
Si	0·24
S	0·02
P	0·02
Mn	0·66
Ni	Trace
Cr	0·27
Mo	0·49
Cu	0·05

A check upon the initial isotropy of the material was made by means of creep tests at 9 tons per square inch and 550 deg. Cent. on specimens cut in three rectangular directions from the block. The results of these creep tests were quite closely similar and indicated that from the point of view of creep properties the material might be expected to behave isotropically. The above test, however, it must be noted, is not in any sense final, but does indicate a good likelihood of isotropy.

Actually, as will appear later, anisotropy occurred in the subsequent combined stress tests, but this was probably because of the particular order of strain involved in the tests, since it has been found that for several typical engineering materials anisotropy arises in combined stress tests when the strain imposed exceeds an optimum value, although the material be initially isotropic. No indication was, however, given that this anisotropy affected the major issues involved in the investigation.

Tensile creep tests were made on solid specimens of 2in gauge length and diameter 0·357in.

Combined stress creep tests, one pure torsion, and one pure tensile creep test, were made on tubular specimens 2·3in equivalent gauge length, 0·5in internal diameter, and either 0·03in. or 0·02in wall thickness. Loss of wall thickness by oxidation proved to be inappreciable.

The grain size of the material was sufficient

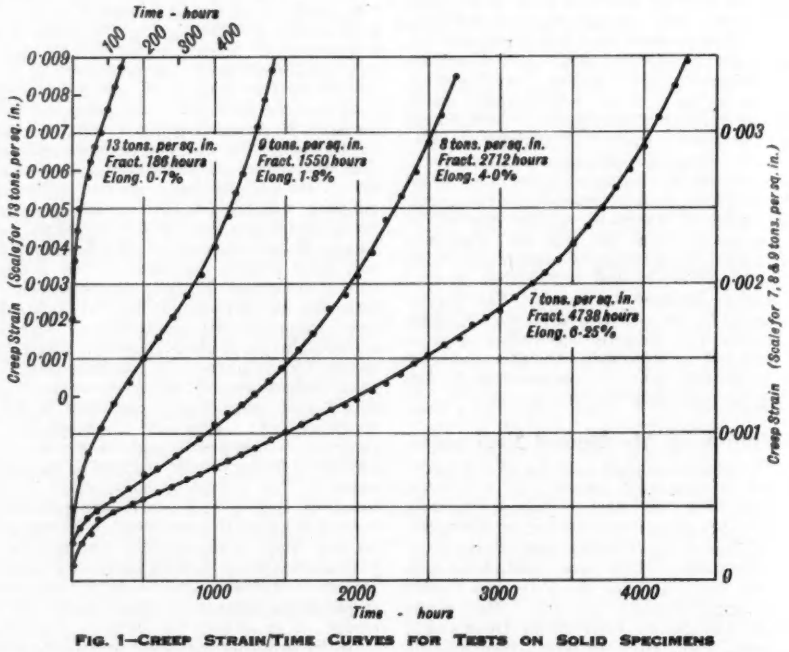


FIG. 1—CREEP STRAIN/TIME CURVES FOR TESTS ON SOLID SPECIMENS

* Communication from the National Physical Laboratory.

† Details of the creep behaviour of this material under tensile creep test conditions are given in another paper.[2]

to provide an average of six grains to the wall thickness of the tubular specimens. In previous combined stress work this has proved sufficient to provide a characteristic cross section.

Results of Creep Tests

In Fig. 1 and Table I creep strain/time curves and detailed results are given for the initial group of tensile creep tests to fracture on solid specimens. Fractures occurred over periods ranging between 186 hours for a stress of 13 tons per square inch and 4738 hours for a stress of 7 tons per square inch, with a corresponding range of elongations between 0·7 per cent and 6·25 per cent. It will be noted from the remarks in Table I that fracture was virtually entirely intercrystalline over the range 9 tons per square inch to 13 tons per square inch, but that below 9 tons per square inch some mixing of the nature of the fracture was noted. This, of course, fulfilled expectations. Nevertheless, the fractures in the stress range 13 tons per square inch to 9 tons per square inch were close enough to being completely intercrystalline to make it evident that tests under pure torsion or combined stresses of an equivalent value, might constitute a suitable test of Siegfried's hypothesis and yield information concerning the stress criteria of performance. Fig. 2 shows that for the tensile creep tests on solid specimens a linear relation between stress and log time to fracture was exhibited.

In Figs. 3–5 and in Tables II and III the creep strain-time curves and detailed results of one pure tension, one pure torsion, and three combined stress tests are given. In the case of the latter tests the axial and shear components of strain are given. The stresses in these tests fulfill the above requirements regarding equivalent stress, and include stress ratios $t/s = 9$, 1·8 and 0·5, the first two tests having the same hydrostatic stress as the plain tensile test.

Table I.—*Minimum Creep Rates and Period to Fracture of Solid Specimens (0·357in Diameter) of 0·5 Per Cent Mo Steel at 550 Deg. Cent. Under Pure Tension*

Tensile stress, tons per square inch	Minimum creep rate $\times 10^{-6}$ per hour	Time to fracture, hours	Elongation per cent at fracture ($2\sqrt{\text{area}}$)	Remarks
13	2·6	186	0·7	Virtually entirely intercrystalline
9	$1·3_5$	1550	1·8	Virtually entirely intercrystalline
8	$1·7_5$	2712	4·0	A mixed fracture, possibly three-quarters intercrystalline
7	$0·4_5$	4738	$6·2_5$	A mixed fracture, possibly three-quarters intercrystalline

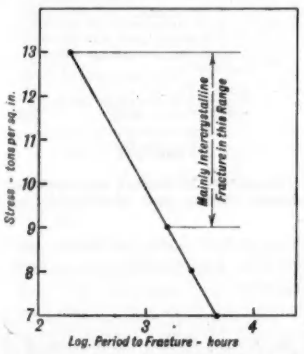
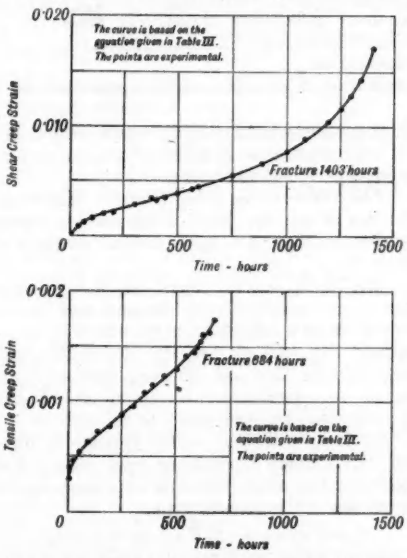


Fig. 2—Stress / Log. Period-to-Fracture Curve for Creep Tests on Solid Specimens

Creep rates for the principal and octahedral planes are computed by means of the normal transformation formulæ.

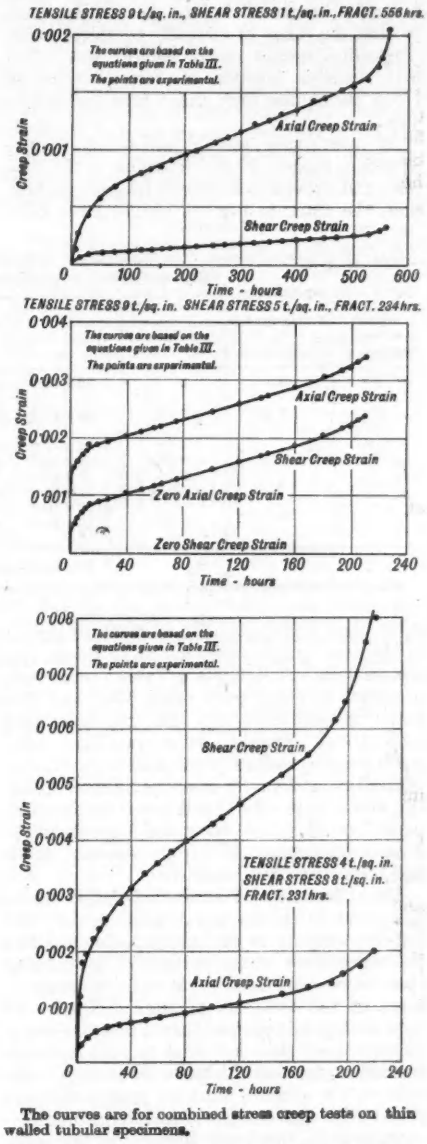

The curve is based on the equation given in Table III.
The points are experimental.
Fracture 1403 hours
Shear Creep Strain
Time - hours
Fracture 684 hours
Tensile Creep Strain

The curves are for a pure torsion creep test at 6·5 tons per square inch and a pure tension creep test at 9 tons per square inch, both on thin-walled tubular specimens.

Fig. 3—Creep Strain Time Curves

Discussion of Results

Application of Siegfried Hypothesis.—After ascertaining the range of tensile stress for intercrystalline creep fracture indicated in Fig. 2 and in Table I, a pure torsion creep test was conducted at a stress of 6·5 tons per square inch, corresponding to an equivalent tensile stress of $11·2_5$ tons per square inch, which is well inside the range of approximately complete intercrystalline cracking for tensile creep tests. Fracture in this test occurred after 1403 hours, and it will be seen from Table II that the fracture itself was purely transcrystalline. The fracture period was considerably in excess of the corresponding period for the equivalent


TENSILE STRESS 9 t./sq. in., SHEAR STRESS 1 t./sq. in., FRACT. 556 hrs.
The curves are based on the equations given in Table III.
The points are experimental.
Axial Creep Strain
Shear Creep Strain
Creep Strain
Time - hours
TENSILE STRESS 9 t./sq. in. SHEAR STRESS 5 t./sq. in., FRACT. 234 hrs.
Zero Axial Creep Strain
Zero Shear Creep Strain
TENSILE STRESS 4 t./sq. in.
SHEAR STRESS 8 t./sq. in.
FRACT. 231 hrs.

The curves are for combined stress creep tests on thin walled tubular specimens.

Figs. 4 and 5—Creep Strain / Time Curves

Table II.—*Minimum Creep Rates and Period to Fracture of Thin Walled Tubular Specimens of 0·5 Per Cent Mo Steel at 550 Deg. Cent. under Pure Tension, Pure Torsion, and Combined Stress Systems. (All Stresses in Tons Per Square Inch.)*

Tensile stress t	Torsion stress s	Principal stresses ($\sigma_2 = 0$) σ_1	σ_3	Maximum stress deviator $\frac{1}{2}(2\sigma_1 - \sigma_3)$	Hydrostatic stress $\sigma_1/3$	Max. shear stress $(\sigma_1 - \sigma_3)/2$	Octahedral stress $\sqrt{\frac{2}{3}}\sqrt{t^2+3s^2}$	Min. axial creep rate $\times 10^{-6}$ per hour	Min. shear creep rate $\times 10^{-6}$ per hour	Principal creep rates $\times 10^{-6}$ per hour C_1	C_2	C_3	Octahedral creep rate C_0 $\times 10^{-6}$	Time to fracture, hours	Remarks
										per hour	per hour	per hour	per hour		
9	0	9	0	6	3	4·5	4·23	1·7	—	1·7	$-0·8_5$	$-0·8_5$	2·4	684	—
0	6·5	6·5	−6·5	6·5	0	6·5	5·32	—	5·3	$2·6_5$	$-2·6_5$	0	4·3	1403	Transcrystalline fracture
9	1	9·11	−0·11	6·11	3	4·61	4·32	$2·0_5$	0·33	2·2	0·5	−2·7	4·1	556	Mainly intercrystalline. Some transcrystalline portion
9	5	11·2	−2·2	8·2	3	6·7	5·9	6·7	6·7	8·2	−0·8	−7·4	12·7	234	Mixed fracture. Partly intercrystalline, partly transcrystalline
4	8	10·25	−6·25	8·92	1·33	8·25	6·8	4·5	17·1	11·1	−6·4	−4·7	15·8	231	Mixed fracture. Roughly equal portions of transcrystalline, and intercrystalline

stress tensile creep test. Thus far the investigation gave some support to the Siegfried theory, inasmuch as a stress system in which the hydrostatic element was entirely absent gave rise to transcrystalline failure after a comparatively prolonged period.

Two further tests were now made in which a tensile stress of 9 tons per square inch (within the range of virtually complete intercrystalline tensile creep failure) was allied with torsion stresses of respective value 1 ton per square inch and 5 tons per square inch.

As previously noted, according to the Siegfried theory, if the fracture in the two tests had proved to be purely intercrystalline, then the fracture periods should have been equal, and equal also to the fracture period in the test, under pure tension at 9 tons per square inch. Actually (see Table II) fracture occurred in these tests after 556‡ and 234 hours respectively, and the fractures were respectively mainly intercrystalline with some transcrystalline parts, and partly transcrystalline and partly intercrystalline. Again the above periods differed from the fracture period of the test on a solid specimen at 9 tons per square inch pure tension which had broken in 1550 hours.

Here, however, a secondary issue arose. Comparative plots—e.g., Fig. 9, of the tensile creep tests on solid specimens, and the three tests so far performed on tubular specimens—indicated that the characteristics of the two sets of tests differed. It appeared possible that this difference arose largely from the fact that in the tubular specimens the wall thickness would only contain on the average some six grains, as compared with the comparatively large number contained in the cross section of the solid specimens. Accordingly a further test was made on a tubular specimen at 9 tons per square inch pure tension. This test fractured in 684 hours, and its characteristics were consistent with those of the other tests on tubular specimens.

Obviously, therefore, the periods of fracture of the two combined stress tests and the test on the tubular specimen in tension at 9 tons per square inch did not agree. Accordingly the tests concerned did not constitute a confirmation of the Siegfried hypothesis, but underlined the fact, previously anticipated, that the general type of fracture occurring under combined stress conditions might be expected to be neither completely transcrystalline nor intercrystalline.

In virtue of the fact that the evidence of the tests discussed above concerning the Siegfried criterion was somewhat indefinite, though on the whole apparently unfavourable, it was obviously desirable to examine the features of the tests, and to note whether any other criteria of performance suggested themselves. This examination is the subject of the following paragraphs.

Obviously the generality of any criterion operating would need to be established for a range of stress systems, and accordingly a further combined stress test in which a tensile stress of 4 tons per square inch and a torsion stress of 8 tons per square inch were applied was made. This test had a ratio of $t/s=0\cdot5$, as compared with 9 and 1·8 in the other two combined stress tests, the three tests covering an appreciable range of stress ratios. Reference to Table II indicates that the fracture in the case of the test at 4 tons per square inch tension and 8 tons per square inch torsion was of roughly equal proportions of transcrystalline and intercrystalline nature after a period of 231 hours.

TABLE III.—*Pure Tension, Pure Torsion, and Combined Stress Tests of a 0·5 Per Cent Mo Steel at 550 Deg. Cent. Values of Constants in the Equation* $\varepsilon=C\,[K_1t+At^{\cdot33}]+Be^{K_2t}$

Tensile stress t tons/sq. in	Torsion stress s, tons/sq. in	C	A	K_1	B	K_2	Creep curve
9	0	1	$1\cdot22\times10^{-4}$	$6\cdot64\times10^{-7}$	3×10^{-9}	0·013	Axial only
0	6·5	2·83	$1\cdot22\times10^{-4}$	$6\cdot64\times10^{-7}$	$2\cdot8\times10^{-5}$	0·0043	Shear only
9	1	1·18	$1\cdot22\times10^{-4}$	$6\cdot64\times10^{-7}$	$6\cdot7\times10^{-14}$	0·04*	Axial
		0·198	$1\cdot22\times10^{-4}$	$6\cdot64\times10^{-7}$	$1\cdot1\times10^{-14}$	0·04*	Shear
9	5	2·36	$1\cdot22\times10^{-4}$	$6\cdot64\times10^{-7}$	10^{-6}	0·039	Axial
		2·36	$1\cdot22\times10^{-4}$	$6\cdot64\times10^{-7}$	10^{-7}	0·039	Shear
4	8	1	$1\cdot22\times10^{-4}$	$6\cdot64\times10^{-7}$	10^{-6}	0·056	Axial
		1·63	$1\cdot22\times10^{-4}$	$6\cdot64\times10^{-7}$	$2\cdot33\times10^{-6}$	0·056	Shear

* See, however, remarks in test.

On combined stress tests C and B have component values. C and B are, of course, dependent upon stress functions.

The Nature of the Creep Curves.—The creep curves of the five tests of tubular specimens shown in Figs. 3–5 have several features of note.

The creep curve forms in the primary stage are geometrically similar and in all cases reach a minimum rate, which is maintained for various periods, depending presumably in the case of each stress system upon the particular development of the process leading eventually to failure.

In all tests tertiary creep appears to have an exponential dependence upon time. For all tests the creep curve is expressed by an equation of the general type.

$$\text{Creep strain } \varepsilon=C[K_1t+At^{\cdot33}]+Be^{K_2t},$$

where C, A, K_1 and K_2 are constants and t is time. Individual values of the constants are given in Table III. The first two terms are of major importance in the primary and secondary stages, and the third in the tertiary stage.

Reference to Table III indicates that A and K_1 are of the same values for all tests, and component strains giving effective geometrical similarity in the primary and secondary stages for all stress systems. B and K_2 vary with the stress system,§ and the data is too fragmentary to give any clue as to the stress dependence of these factors. Nevertheless, the curves shown in Figs. 3–5 are based on these equations and obviously follow the experimental points very well.

Thus, while much further work is needed to indicate the significance of the terms of type Be^{K_2t}, their occurrence is to be noted as a quite definite feature of all these tests.

Analysis of the tensile creep tests on the solid specimens indicates that they also very closely follow a relation of the above type, where, however, the values of K_1 and A, though constant for all tests on solid specimens, differ from the values for tubular specimens. Also the power of t in the second term is 0·2, not 0·33. B and K_2 again vary at all stresses, K_2 increasing over the range 7 tons to 13 tons per square inch, but appearing to tend to a minimum value at the low stresses.

Incidentally, as observed earlier in the test, the tertiary portion of the curve for the test at $t=9$ tons per square inch, $s=1$ ton per square inch may have been shortened somewhat artificially, and this appears to lead to a value of B artificially low, and a rather high value of K_2.

The second feature of these curves is indicated by a comparison of the axial and shear creep curves in the three combined stress tests. For isotropic behaviour the ratio of the axial to shear creep rates should be an approximation to the stress ratio $t/3s$. Reference to Table II indicates that this is certainly not so, the ratios for the three tests concerned being 6·2, 1 and 0·26, as opposed to the isotropic values of 3, 0·6 and 0·17. The material has thus behaved anisotropically. This anisotropy appears very likely to have arisen from the degree of strain involved in the tests, and does not necessarily show that the indication of isotropy given by the initial tests was incorrect. Judging from the relatively sparse data available, it appears unlikely that expressions less complex than those of type

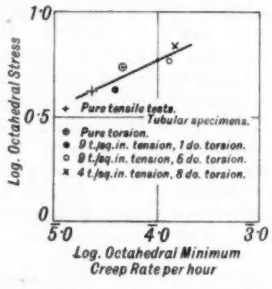


FIG. 6—RELATION BETWEEN OCTAHEDRAL MINIMUM CREEP RATE AND OCTAHEDRAL STRESS

$$C_1=(F)[A(\sigma_1-\sigma_2)-B(\sigma_2-\sigma_1)]f(t),\ \&c.,$$

where A, B and C are constants, F a stress invariant function, and $f(t)$ a function of time, would represent the anisotropy present.

One further point in regard to these tests may be noted. Previous combined stress tests conducted at the N.P.L. on isotropic materials at various temperatures have indicated that the primary and secondary creep strain obeys the Hencky or shear strain energy criterion of plastic flow. Correspondence with this criterion involves a continuous relation for all stress systems between octahedral shear stress and octahedral plane creep rate.

Fig. 6 shows that such a correspondence exists for the present material. The points for individual tests are disposed in a manner which indicates that a continuous curve may reasonably be drawn through them. It appears, therefore, that the primary and secondary creep of the present material quite closely follows the Hencky criterion of plastic flow, despite the anisotropy present.

Criterion of Fracture.—The preceding paragraph has indicated that the features of the earlier portions of the creep curve for the material tested are quite similar to those of other materials subjected to combined stress creep tests at the N.P.L.

Since the complex stress fractures examined are of a mixed nature, it is obvious that the Siegfried fracture criteria of maximum stress deviatior, or hydrostatic stress, are hardly likely to apply. Consideration of Table II makes this self-evident in the case of the hydrostatic stress. Acquaintance with

‡ In this test, however, some indication was given that the fracture may have been accelerated a little in its final stages, on account of an individual crack opening on one side of the specimen, and giving rise to some slight bending action by the load. It is possible that the figure 556 hours should really be, say, 580 hours.

§ It is to be noted here that the values of C and B in the combined stress tests are component values for axial and shear directions. Both C and B are, of course, anisotropic functions of the imposed stress system.

short-period fractures of brittle or ductile materials suggests that the criteria of maximum principal stress or maximum shear stress might operate, while the fact that the material appears to follow the Hencky criterion of plastic flow in the primary and

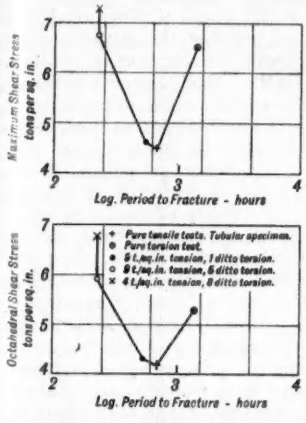

Maximum Shear Stress tons per sq. in.
Log. Period to Fracture - hours
Octahedral Shear Stress tons per sq. in.
+ Pure tensile tests. Tubular specimens.
• Pure torsion test.
• 9 t./sq.in. tension, 1 ditto torsion.
○ 9 t./sq.in. tension, 6 ditto torsion.
× 4 t./sq.in. tension, 8 ditto torsion.
Log. Period to Fracture - hours

FIG. 7—MAXIMUM SHEAR STRESS AND OCTAHEDRAL SHEAR STRESS CURVES

secondary stages suggests that the octahedral stress or shear strain energy as measures of the Hencky criterion might conceivably influence the conditions of fracture in some degree.

Accordingly in Figs. 7, 8 and 9 a plot of

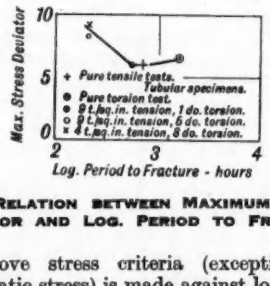

Max. Stress Deviator
+ Pure tensile tests. Tubular specimens.
• Pure torsion test.
• 9 t./sq.in. tension, 1 do. torsion.
○ 9 t./sq.in. tension, 6 do. torsion.
× 4 t./sq.in. tension, 8 do. torsion.
Log. Period to Fracture - hours

FIG. 8—RELATION BETWEEN MAXIMUM STRESS DEVIATOR AND LOG. PERIOD TO FRACTURE

the above stress criteria (excepting the hydrostatic stress) is made against log period to fracture. It is evident that a continuous relation is given only by the plot of the maximum principal stress. It thus appears

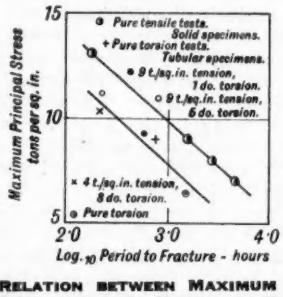

Maximum Principal Stress tons per sq. in.
• Pure tensile tests. Solid specimens.
+ Pure torsion tests. Tubular specimens.
• 9 t./sq.in. tension, 1 do. torsion.
○ 9 t./sq.in. tension, 6 do. torsion.
× 4 t./sq.in. tension, 8 do. torsion.
• Pure torsion
Log.10 Period to Fracture - hours

FIG. 9—RELATION BETWEEN MAXIMUM PRINCIPAL STRESS AND LOG. PERIOD TO FRACTURE

that this criterion represents the results most adequately. The actual relation for this material appears to be

$$\log_{10} P = 4 \cdot 66 - 0 \cdot 22 \sigma_1,$$

where P is the period to fracture in hours and σ_1 is the maximum principal stress in tons per square inch.

Conclusions

(1) A range of pure tensile stress exists in which for this material creep fracture is virtually intercrystalline.

(2) Under no other stress system is (1) true however, the fracture in all cases being of a mixed nature, except transcrystalline in pure torsion.

(3) As would be expected from the Siegfried criterion, the results of the pure torsion test indicate that the fracture in this test was transcrystalline, and the fracture period in considerable excess of that in an equivalent tensile creep test.

(4) No other evidence in favour of the Siegfried hypothesis arises from this work.

(5) All creep curves for this material are of the form expressed by the equation

$$\text{Creep strain} = C[K_1 t + At^n] + Be^{K_2 t},$$

where c, K_1, A, n, B, and K_2 are constants. The bracketed expression describes primary and secondary creep, and the other expression tertiary creep.

(6) The material behaves anisotropically in the range of stresses imposed. This anisotropy probably arises from imposed strain.

(7) Primary and secondary creep follow the Hencky criterion of plastic flow.

(8) The criterion of fracture appears to be the maximum principal stress and is expressed by the relation

$$\log P = 4 \cdot 66 - 0 \cdot 22 \sigma_1,$$

where P is the period of fracture in hours and σ_1 is the maximum principal stress in tons per square inch.

Acknowledgments

The authors wish to acknowledge helpful criticisms and suggestions by Mr. H. J. Tapsell, of the Engineering Division, N.P.L.; and help of Miss Heathman, of the same division, in carrying out the work. The work described was carried out in the Engineering Division of the National Physical Laboratory as part of the programme of the Mechanical Engineering Research Board, and this paper is published by permission of the Director of the National Physical Laboratory and the Director of the Mechanical Engineering Research Organisation of the Department of Scientific and Industrial Research.

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The Institute of Metals

No. III—*(Continued from page 421, March 30th)*

ON Thursday, March 15, 1951, the first papers presented were :—

MODIFICATION IN ALUMINIUM-SILICON ALLOYS

By B. M. Thall, M.A.Sc., Ph.D., and Professor Bruce Chalmers, D.Sc., Ph.D., Member

Synopsis

In the modification of aluminium-silicon alloys by small additions of sodium, the properties and structure of the alloys are substantially improved. Various explanations of this improvement have been proposed, none of them entirely adequate; moreover, some of the experimental data on modification are contradictory. In the present work, thermal data on the modified aluminium-silicon alloys have been redetermined, and semi-quantitative determinations of the sodium content have been made by means of a radioactive technique.

The results have led to the formulation of a new theory of modification based on the influence of sodium on the balance of interfacial tensions during solidification. All the experimental facts are accounted for by applying this theory to the mechanism of eutectic solidification.

THE SOLUBILITY RELATIONSHIPS IN THE ALUMINIUM-SODIUM AND ALUMINIUM-SILICON-SODIUM SYSTEMS

By C. E. Ransley, Ph.D., F.I.M., Member, and H. Neufeld, B.Sc., Junior Member

Synopsis

The solid solubility of sodium in aluminium has been determined by direct measurement of the amount dissolved when high-purity aluminium is immersed in liquid sodium. The solubility is approximately 0·002 per cent in the range 650 deg. to 550 deg. Cent. and appears to have a very small temperature coefficient. The data obtained allow a calculation to be made of the rate of diffusion of sodium in solid aluminium. The liquid-miscibility boundary in the binary system has also been redetermined; the monotectic composition is found to be 0·14 per cent sodium, and the solubility of sodium in liquid aluminium increases smoothly from this value to 0·25 per cent at 775 deg. Cent.

It is shown that when aluminium containing silicon in solid solution is heated in liquid sodium, a ternary compound is formed as a surface layer or sub-scale. By means of experiments in which aluminium strips with different silicon contents were exposed to the action of sodium for prolonged periods, it has been possible to derive approximate values for the concentration of silicon and sodium in solid solution in equilibrium with this compound at various temperatures. The equilibrium silicon contents determined are: 600 deg. Cent., 0·15 per cent; 550 deg. Cent., 0·04 per cent; 500 deg. Cent., 0·01 per cent; the corresponding sodium contents are in the range 0·0016 per cent to 0·0005 per cent. Since the compound is stable to high temperatures (above 800 deg. Cent.), a similar procedure could be used to determine the liquidus isothermals in the primary field of the compound. Only one compound has been observed; its composition has not been precisely determined, but appears to be based on $[NaAlSi_{1\cdot25}]$ or $[NaAlSi_{1\cdot22}]$. On the basis of the liquid solubility results obtained, a tentative diagram for the aluminium-silicon-sodium system is put forward, indicating a ternary eutectic at about 0·017 per cent sodium.

Discussion

Mr. H. W. L. Phillips (metallurgist, British Aluminium Company, Ltd.) said that the application of the radioactive tracer technique described by Thall and Chalmers was a novel treatment of the subject, for which the authors should be given all credit, and it was disappointing that after taking up so much time and trouble in working out the method they should have got so little out of it, since all that they had discovered had been suspected as long ago as 1925. He was not at all sure that the guarded conclusions in the paper generally could be taken as correct, since they were based on insufficient evidence.

Mr. D. McLean (Metallurgy Division, National Physical Laboratory) drew attention to a possible discrepancy between the experimental results and the explanation given by Thall and Chalmers. The authors found that the freezing point of the modified eutectic was reduced by modification, the reason being that extra free energy was necessary to overcome the increased surface energy. Their explanation was that the surface tension and therefore surface energy between solid silicon and solid aluminium was reduced. He supposed it was possible that the effect of the modifying agent could reverse as between solid silicon and liquid aluminium and solid silicon and solid aluminium, but that seemed to be rather unlikely. He therefore suggested that there might be this discrepancy between the authors' results and their theory. Perhaps it was possible to construct a theory on the basis of surface tension consistent with the experimental facts by investigating the variation in the probability of nucleus formation of silicon with temperature and with surface energy.

Dr. E. Scheur (head of laboratories, Inter-

national Alloys, Ltd.) said that on the constitution of the aluminium-solid silicon diagram the paper by Ransley and Neufeld had given that diagram a shape which was quite convincing, and he doubted whether anything fundamentally new for the study of the modification process could be expected in future. He was interested in the explanation by Thall and Chalmers of the sustained undercooling of the aluminium-silicon eutectic. Their explanation was identical with an idea which he had put forward in 1936, but it was now incorporated in a theory which explained in a simple way the most important point of modification phenomena. The only thing which he did not feel competent to judge was whether the assumption that such a small addition of soluble substance could reduce surface tension to such an extent as to produce the effects described.

The following two papers were then read :—

SHEARING OF METAL BLANKS

By T. M. Chang, Ph.D., B.Sc. (Eng.)

Synopsis

The results are given of investigations on the effects of clearance, tool shear and tool curvature in the shearing of circular blanks. The materials tested included cast iron, mild steel, brass, copper, zinc, aluminium, and lead, ranging in thickness from 0·036in to 0·500in. The tools employed had diameter of 1–6in, clearances up to 58 per cent of the thickness of the material, and shears to as much as 356 per cent.

Altogether four separate sets of apparatus and recording systems were used, and the results show : (i) that the basic modes of fracture in blanking are essentially the same as those in bar shearing described in a previous paper (*Journal*, Inst. Metals, 1950–51, 78, 119) ; (ii) that the provision of an optimum clearance on the tool has the desirable effect of reducing both the maximum blanking load and the shearing work, the optimum clearances recommended being as follows : cast iron, 5–10 per cent ; mild steel, 5–10 per cent ; brass (70 : 30), 0–10 per cent ; copper, 0–10 per cent ; zinc, 0–5 per cent ; aluminium, 0–5 per cent ; lead, 0 ; and finally (iii) that the characteristics of tool shear can be derived from those of a flat punch by a graphical construction.

SHEARING OF METAL BARS

By T. M. Chang, Ph.D., B.Sc. (Eng.), and Professor H. W. Swift, M.A., D.Sc. (Eng.)

Synopsis

Stresses, metal flow and crack propagation in the shearing of ½in thick bars of most industrial metals have been studied. It is found that there are two chief modes of fracture in shearing without clearance. Ductile materials undergo a bodily sliding action along the line of shear with the displaced particles maintaining their adhesion until final separation at full punch penetration. Other materials develop cracks, and the separation of the metal occurs either when one of the cracks propagates itself through the whole thickness of the bar or when the cracks from the punch and die meet ; tongues of metal develop in the former case, while a clean fracture results from the latter.

Clearances up to 30 per cent of the metal thickness were investigated, and optimum clearances for a clean fracture and least strain work are found to range from zero for ductile materials, such as lead, tin and aluminium, to between 5 and 10 per cent for the harder metals, such as copper, brass and mild steel.

The effects of dullness of cutting edge and of tensile overstrain have also been assessed. These two factors tend to increase the maximum shearing load ; but, whereas dullness increases the punch penetration at failure, overstrain tends to reduce it.

Finally, an attempt has been made to correlate the stresses in shearing and tensile tests, but there seems to be no definite and useful relationship between these two tests.

Mr. J. F. Harrington (Assistant to Production Engineer, the Royal Mint) observed that in the papers there was no comment on the lubrication problems that occurred and which, from a practical point of view, were of considerable importance.

Mr. Tomlinson (British Aluminium Company, Ltd.) felt that the two papers would be very enlightening both to engineers and to metallurgists. He then described work done by his own company on the correct clearance for the production of rivet holes in thick aluminium alloy plate. One of the points brought out by Dr. Chang was the different results that might be obtained by punching holes of the same diameter in different materials. It was important to note that some of the higher-strength aluminium alloys required a clearance which was markedly different from that required in the case of pure aluminium. For the alloys the angle of clearance seemed to be smaller than for pure aluminium.

Dr. T. Ll. Richards (research physicist, I.C.I., Ltd., Metals Division, Birmingham) said that the work described in the papers showed that there was in tests of this kind no better approach than the direct approach. He did not agree with the comment that there was no connection between shear stress and tensile stress. In trying to analyse the data in work which he had done, he had found it very significant that the ratio was about 0·5 for hard material. When trying to read more into the variation of the shear stress / tensile stress ratio for materials of different degrees of hardness, from 0·7 to 0·5, and allowing a bit for the local deformation, it had been found that the difference between the 0·7 for soft material and the 0·5 for hard material was largely due to the fact that in ordinary tensile deformation with free straining there was considerable elongation and work hardening, whereas with hard material when a critical shear stress was reached the material just fractured.

Mr. J. W. Jones (College of Aeronautics) wondered whether the authors had in any way explored the influence of temperature on their results. Had they any information of the difference of temperature of the sheet on one side when it began to shear and on the final side when the shearing was complete ? A very big factor influencing temperature would be the thickness of the material, and he saw no definite relationship between the thickness of the material and the clearance values suggested. There was reason to believe that with small increases in temperature there was a tendency to affect machinability. He felt that in shearing problems the temperature factor needed very serious consideration. There was reason to believe that very high temperatures were formed, it might be locally, and this raised the question of time for heat diffusion in a section and of thickness of the material and rate of relative movement of punch and work.

The Institution of Naval Architects

No. IV—(*Continued from page 409, March 30th*)

On Thursday afternoon, March 15th, the following paper was presented and discussed :—

HIGH-SPEED SAILING

By H. M. Barkla, M.A., B.Sc.

Summary

Experiments such as those of the Stevens Institute have been carried out only on conventional yachts, and such theory of sailing as exists has been similarly restricted to a small range of variations. To handle the problem in a more general manner, relating all the relevant variables, a graphical method of solution has been evolved. Containing implicitly the corrections to be made to the direction and strength of the wind in virtue of the vessel's own motion, it is particularly apposite to the consideration of high-speed sailing. In this paper it has been applied to the speed range above the speed/length ratio of 2, and the results are remarkable. The sail area necessary to give speeds of the order of 30 to 40 knots in winds of 20 to 30 knots is only about 400 square feet per ton, but the required stability is far beyond the limits of a single hull. Such a combination may, however, be obtained by multiplying hulls and aerofoils. The triscaph or three-hulled vessel described is believed to typify a class of vessel which might inaugurate a new era of sailing and terminate a half century of arrested development.

Discussion

Dr. J. F. Allan said that he was satisfied that the author's theoretical treatment of the subject was correct, and that his conclusions were reasonable.

He wondered whether speed was really wanted in yachting. The author, however, appeared to accept the view that more and more speed was desirable, but there were still occasions when it was a leisurely pastime.

The 1·5 speed/length ratio hump was the obvious limitation on what could be done with the conventional yacht, and to get over that hump it was necessary to increase the sail area enormously, and that was not a practical proposition. The limiting speed of an ocean racer was a little below the 1·5 hump, and he doubted if it was a seaworthy idea to push such a vessel beyond the 1·5 hump in the conditions in which the wind would be available to produce the necessary forces.

It was a general experience that in rough water planing boats were very uncomfortable, and it was probable that, in weather conditions which permitted speeds of 40 knots, it would not be reasonable to drive a boat at 30 or 40 knots. In protected estuaries conditions may permit the use of the full properties of the vessel described in the paper, and he felt that the idea would appeal to a reasonable number of younger yachtsmen if that type of boat were developed and put on the market at a reasonable price. The boat did not appear to be a commercial or a Service proposition, for to-day both in commercial and in Service matters it was essential to do things in a given time and not depend on the local conditions.

Mr. K. C. Barnaby, in a written communication, said Catamaran yachts constructed on the principles put forward in the paper would no doubt "ghost" along in light airs owing to the large sail area/displacement ratio, but it was doubtful if they would often be able to take advantage of their high speed potentialities. Small hydroplanes were extraordinarily sensitive in rough water, and he saw no reason to suppose that a sailing hydroplane would be any less sensitive than a power hydroplane. If water was more viscous, a combination of high winds and smooth seas would be possible, but actually when the wind was right for high speed the surface conditions would render it impossible. Such a craft would not comply with Froude's definition of a yacht as combining habitability with speed, but by fitting it with wheels it could be used as an ice or land yacht during winter.

Mr. W. J. Westell urged that a distinction should be drawn between Mr. Barkla's theory and his proposed form of vessel. In the paper only one sketch of a possible vessel was given, and it might lead people to suppose that the whole thing was fantastic. As the author had stated, there were many different ways of putting into practice the theories brought forward and whether people would build such boats was largely one of cost. Whether or not high-speed boats

should be used for offshore sailing or ocean racing depended entirely on a safety device being developed to prevent a boat being turned over should it hit a bad formation of waves. He was convinced that it was necessary to have a smaller planing type of boat for inshore racing, to reach a speed of the order projected.

Mr. C. A. Lyster commented on the author's method of dealing with the enormous number of variables with which a yacht was confronted.

The objection to that particular form of motion on water could be based on two grounds. Seaworthiness was a very serious problem, and to travel over water at high speed could be extremely shattering if the sea was not glass smooth. When the high-speed vessels were developed during the war they could keep the sea in all kinds of weather, but could not keep their speed. It was not possible to drive at really high speed in rough water, and the suggestion that high-speed sailing vessels could avoid storms by sailing away from them would defeat its object, which was to reach their destination.

The second objection was the difficulty of control, and he mentioned that the difficulties of steering a high-speed ocean racing yacht before the wind, or in a strong wind and rising sea, were so great that the helmsmen must be relieved at intervals of a quarter of an hour.

Triscaphs or biscaphs must have considerable strength if they were to sail in anything but calm water, for flying boats which came down on a rough sea seldom lasted more than twenty minutes, and if the author was taking a flying boat structure as an indication of strength there was not much hope in that direction.

Mr. F. E. M. Ducker recalled having devised a means of solving the problem of sailing ship performance, but Mr. Barkla had adopted a more mathematical approach. The number and relationship of the variables in the problem of the sailing ship were such that he did not think a purely mathematical solution to performance was possible, and recourse to graphical methods seemed inevitable.

Dr. J. F. Leathard said that the author was out to produce a type of boat having a greater sail area than was normal, in order to obtain a greater lift force from the sails by adopting a more rigid aerofoil sail in place of the normal canvas and by a multi-hull arrangement.

He considered that aerofoil sails were an improvement and that the multi-hull was sound if the conditions were ideal. The fore-and-aft stability for such a boat would be of supreme importance, and he suggested that the proposal of some sort of freedom of movement for the three floats would rather cause instability than improve stability.

The drawing of the triscaph yacht contained a novel feature in the proposal to tilt the aerofoil inwards. That assisted stability by producing a righting moment on the aerofoils from the lifting force, which was acting in the same direction as the actual righting moment of the hulls.

Major-General Parham said that the greatest point in favour of stiff sails was control, and twin hulls enabled the acrobatic balancing, which was necessary in yachts, to be avoided.

Mr. P. V. MacKinnon felt certain that the use of aerofoils was necessary in strong winds, and that the adoption of a double or even treble hull was correct. The wind was not always blowing at 25 knots or even at 15 knots, and the greatest problem was to reach a high ratio of ship's speed to wind speed under moderate wind conditions. That was a difficult problem to solve when the object was to sail the boat down wind as fast as possible.

Mr. Barkla replied that he was encouraged by those who had agreed on the soundness of his mathematical analysis. With regard to safety in broken water and the suggested danger of flipping over, he recommended that there should be a panic button such that, if the windward hull were coming out of the water, the rudder was placed central to reduce the air forces immediately.

The idea of tilted aerofoils was not new; it had been applied in the United States.

The final paper read and discussed on Thursday afternoon, March 15th, was :—

INFLUENCE OF SHIP FORM ON TRANSVERSE STABILITY

By Professor C. W. Prohaska, Dr. Techn.

Summary

For a series of ship forms, comprising forty-two forms having fullness coefficients selected to cover at least the merchant ship field, stability calculations have been carried out. The results are presented in non-dimensional form as C_{RS} curves. An analysis of the C_{RS} variations due to change in ship form has been attempted and broad conclusions have been drawn. The results have been compared with those which could be derived from the author's earlier work in this field.

A new method for rapid calculation of stability curves is presented. It is approximate, but the degree of approximation is shown to be at least comparable to that obtained by the "exact" methods. It has the special advantage that the stability curves obtained are more easily verified by comparison with those derived for other forms, because, by the new method, the influence of each of the different form parameters used is clearly detected.

Discussion

Professor A. J. Sims said that the paper was worth serious study, but questioned the title, as most of the paper contained a new and ingenious method of investigating the stability of a ship. In a discussion on the previous day on the basic principles of resistance to propulsion of ships, doubt was raised about some of the methods employed, and he felt it would be a pity if any doubt was raised about stability curves obtained by the orthodox methods. He believed that a user who was prepared to check his intrument and to understand it so that the integrator could be used in the most efficient manner, should obtain results of a high order of accuracy.

One disadvantage of Professor Prohaska's method was that after getting the initial parameters the rest of the process became mechanical, and it was difficult to be certain that a mistake had not been made. Another disadvantage was the tabular presentation. He was doubtful whether, in a well-equipped design office, the method would receive wide application.

Mr. K. G. McBride said he believed the P method was advocated especially for warships and other types of ships in respect of which accurate information was required in the early stages. The advances claimed were worthy of consideration, particularly the drawing of the residuary resistance curves and the correction curves below.

Although the P method of calculation claimed an increase in speed, against that must be set the extra hydrostatic calculations mentioned in the section of the paper giving suggestions to facilitate the use of the new method. With regard to the adoption of the method in the design office, he did not think that additional work on hydrostatics would have a great bearing on the matter.

Sometimes the method was not applicable to a particular form, so that an understanding of the basic principles of the method was necessary before it could be applied to a particular ship. A certain amount of caution appeared to be necessary in regard to the application of the method. Against the P method we had the choice of the integrator method for accurate work, and there appeared to be no reason why the advantageous presentation of results should not be applied to the integrator method, if desired.

The C_{RS} diagram showed quite good comparisons under certain conditions, and to obtain a more accurate production of the stability curves the P calculating method had been introduced, which seemed to be widening the subject. He said the paper presented a wide analysis of the effect of the ship's form of stability; that analysis was valuable for practical use, and gave a new method which, although apparently limited in one or two ways, had possibilities in regard to stability calculations.

The Chairman (Mr. Woollard) said he believed the stability of ships was the only branch of naval architecture which was exact, and although methods would be improved, the theory could not change. He was not convinced that the integrator method was so unreliable, or called for so much labour, as Professor Prohaska had suggested.

He felt that under certain circumstances it was important that approximate methods should be sought and brought forward, and the mathematics of the paper, he continued, need not worry the calculator.

Professor Prohaska, in reply to Mr. McBride, said he had not intended to imply that the new method was to be used especially for warships; but it could be used with advantage in connection with such ships and passenger ships and others, where accurate information was required in the early stages. He could not agree that the method was not applicable to all forms; there was no need to be cautious about its general application.

He appreciated that his method would not be accepted readily without proof, and that all interested would need to apply it at some time to see how it worked out, and he hoped that somebody would do that, because he believed it would prove to be a short cut in stability calculations.

Institute of Marine Engineers' Annual Report

The annual report of the Institute of Marine Engineers shows that the membership continues to increase, the overall total standing at 6434 on December 31, 1950, representing an increase in the roll of 245. The introduction of a new class of members is mentioned, namely, that of Probationer Students, who will be subject to sponsorship and will be admitted without examination. There is a list of the papers read and discussed and also of those published in the "Transactions." The alterations to by-laws are recorded; it is noted that investigations are proceeding with regard to a site for building the new premises, and the amendments to the Tonnage Measurement Regulations are mentioned briefly. It is made evident from the report that the Council and the many committees have had a busy year, including work on the organisation of the International Conference of Naval Architects and Marine Engineers. The reports from representatives are concerned with a large number of activities, among which can be noted the account of the work of the British Shipbuilding Research Association with special reference to the ships' machinery section. There are brief summaries of the more important reports submitted to the British Electrical and Allied Industries Research Association sub-committee and the activities of the abstracting services committee are outlined. The work of numerous standards sub-committees is summarised and the report includes a statement of accounts.

The 300MeV Synchrotron at the Massachusetts Institute of Technology

MEANS for producing elementary particles of high energy are of increasing importance in modern nuclear physics. Elementary particles having energies of from a few hundred thousand electron volts to 20 million electron volts (MeV) or more are required to investigate the simpler processes of the atomic nucleus. Since the mass of the π meson, for example, is about 275 times that of the electron (equivalent mass=$\frac{1}{2}$MeV), energies in excess of 138MeV are required to produce mesons artificially.

Particle Accelerators

Laboratory accelerators, which are able to produce energy in the required ranges, have been developed during the past twenty years. One of the more notable of the machines designed to impart high energy to elementary particles is the cyclotron, which was invented by Ernest O. Lawrence, of the University of California, and his associates, notably M. Stanley Livingston, Associate Professor of Physics at the Massachusetts Institute of Technology (M.I.T.). The electrostatic generator invented by Robert J. Van de Graaff, Associate Professor of Physics at M.I.T., is another mechanism for attaining the high energies required for atomic nuclei studies. Still another is the betatron invented in 1939 by Donald W. Kerst, of the University of Illinois. The newest of such particle accelerators is the synchrotron, originally proposed independently in 1945 by Edwin M. McMillan, of the University of California, and V. Veksler, in Russia. Each of these different kinds of accelerators has its characteristics and advantages, and each has a place in present studies of the ultimate structure of matter.

To understand the basic operation of the different kinds of particle accelerators, it is well to recall how elementary charged particles behave under the influence of electric and magnetic fields. In the presence of a constant and uniform electric field, a slowly moving, low-energy particle is uniformly accelerated and its speed and energy consequently increased. With increased energy, however, the apparent mass of the particle increases; this is sometimes referred to as the relativistic mass increase. Further acceleration will increase the speed of such particles up to, but never quite reaching, the velocity of light. Near the speed of light, an electric field can no longer appreciably increase the speed of a charged particle, but the momentum of the particle increases without limit as the apparent mass increases without limit. On the other hand, a constant and uniform magnetic field produces no force on the charged particle unless the particle is moving. For a particle moving in a uniform magnetic field, the resulting force will be at right-angles to both the velocity and the magnetic field.

Different combinations of electric and magnetic fields are employed in the various particle accelerators used in nuclear physics; a magnetic field which varies with time is always accompanied by an induced electric field, which can also be used for the acceleration of the charged particles.

The cyclotron (Fig. 1) uses a large magnet to keep charged particles moving about in concentric circles. It is a characteristic of the cyclotron that the time required for the particle to complete a circular orbit is independent of the energy of the particle. A radio-frequency oscillator is used in conjunction with the magnet to provide an electric field, which gives a sudden acceleration or "kick" to the particle each time it completes a semi-circular path. In so doing, it increases the energy (and, therefore, the speed) of the particle twice in a circuit. The particle traverses a spiral path of increasing radius and makes a round trip during one cycle of operation of the oscillator. A limit to the maximum energy of the particle is set by the increase in the relativistic mass of the particle. As the mass of the particle increases, it is no longer able to derive the same acceleration from each "kick"; this spoils the resonance condition. The practical limit for cyclotrons is in the neighbourhood of 20MeV for positive particles like protons, deuterons and alpha particles. The energy limit for electrons is well below half a million electron volts, so that the cyclotron is not used to accelerate electrons.

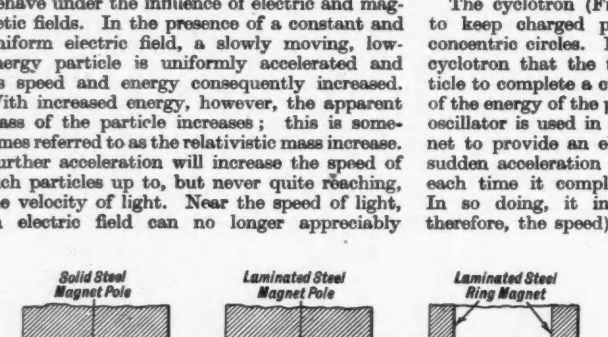

FIG. 1—THREE KINDS OF PARTICLE ACCELERATORS

Other equipment to impart high energy to elementary particles uses straight acceleration by direct voltages in the range up to 5MeV. It is quite costly to obtain such high voltages by rectifying the output of high-voltage transformers, and therefore other means for obtaining the necessary potentials have been developed. The most notable contribution in this field was the development of the electrostatic, or Van de Graaff, generator, which can be used for any charged particles. The output of the equipment is characterised by exceedingly good homogeneity of the beam. So far, practical limits and costs have limited the output of these machines to less than 5MeV, although a 12MeV machine is now under construction by John G. Trump at M.I.T.

The betatron (Fig. 1) has been used only with electrons and the largest machine built so far has produced particles of 300MeV energy. The performance of the betatron is based on electromagnetic induction, the accelerator being identical in principle to the operation of an ordinary a.c. transformer.

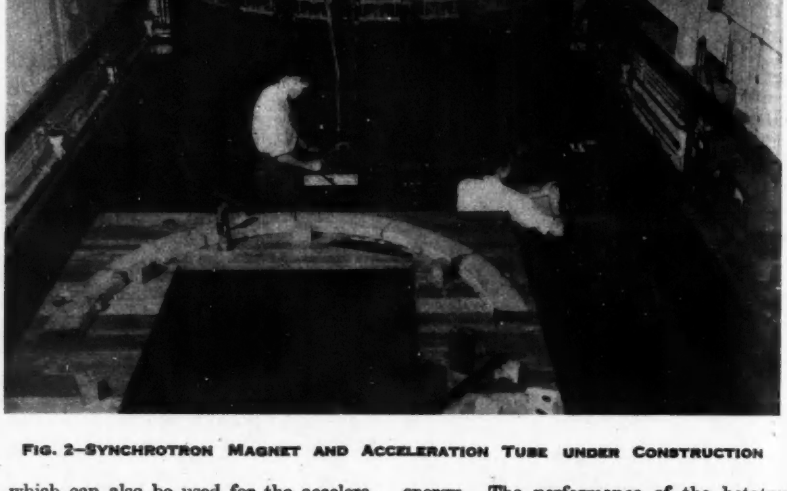

FIG. 2—SYNCHROTRON MAGNET AND ACCELERATION TUBE UNDER CONSTRUCTION

The main difference is that in the ordinary transformer the output current flows in a secondary winding, whereas, in the betatron, the output or secondary current is a beam of electrons flowing in a vacuum. The electron beam is forced to flow into a circular orbit by the strong magnetic field of the magnet. The magnet or transformer core of the betatron serves a dual purpose: it provides the electromotive force and also a focusing force to keep the electrons in a stable circular orbit. It is the twofold purpose of the magnet which establishes a limit to the maximum energy of the particles in the betatron. Because the electrons move at high speed and are simultaneously accelerated inward to move in a circle, they radiate energy in the form of visual light. At higher energies this radiation upsets the balance between the two requirements and thus places the practical limit of energy of the betatron at a few hundred million electron volts.

The sequence of operations in a betatron (Fig. 1) is as follows: (1) by means of a standard electron gun, the electrons are injected into a highly evacuated tube of doughnut shape at about 50kV, immediately after the magnetic field passes through its zero value; (2) the electrons are accelerated by induced electromotive force to the peak value of the machine when the field of the magnet may be, for example, 7000 gauss, and the energy of the electrons has reached 100MeV; (3) the electrons are forced to spiral inward against a tungsten target by a momentary additional magnetic field. When the electrons strike the tungsten target their energy is converted into high-energy X-rays, which penetrate the walls of the tube.

The Synchrotron

The most plausible method of achieving artificial energies approaching the primary

cosmic rays is embodied in the synchrotron. Physically the synchrotron resembles a cross between a cyclotron and a betatron, for it uses radio-frequency power to accelerate the particles and an alternating current magnet to provide a circular orbit and focusing. Since the forces for accelerating and focusing the beam are independent, the synchrotron has fewer design and operating limitations than the betatron. In its simplest form, as used for accelerating electrons, the synchrotron employs a constant frequency r.f. oscillator and accelerates the electrons only after they have nearly reached the velocity of light. For example, in the M.I.T. synchrotron, which is described in this article, the electrons are accelerated from an energy of approximately 2MeV to 350MeV. In this range the electron velocity varies from 98 per cent of the velocity of light to essentially the velocity of light. The electron is brought up to the 2 million volt range by betatron action, so that one can think of the betatron here as a 2MeV injection gun for the synchrotron.

The sequence of operation of such a synchrotron (Fig. 1) is as follows: (1) the electrons are injected at 50kV into a very low magnetic field (8 gauss) exactly as in a betatron; (2) the electrons are accelerated to 2MeV by electromagnetic induction, the magnetic field increasing with time up to 200 gauss; (3) the r.f. voltage is applied across a gap in the orbital path of the electron (Fig. 1) and is kept on until the magnetic field has reached its peak value of 10,000 gauss, 1/250 second after the beginning of the cycle; (4) the electrons are forced to strike a tungsten target by a momentary disturbance in the magnetic field or by turning off the oscillator. Phase (3) is the synchrotron phase.

In principle, the synchrotron resembles a synchronous motor with the electrons (or protons in a proton synchrotron) acting as the rotor. If the magnetic field of the synchrotron magnet were kept at a constant value, the electrons would keep rotating at an energy value corresponding to the field; the electrons would cross the accelerating voltage gap at the time when the accelerating voltage was zero—or at zero phase, in other words. As the magnetic field increases, the radius of the orbit decreases, and so does the time for a particle to make a round trip. Since the particle then arrives at the gap earlier than outlined above, it passes the gap (across which the radio-frequency voltage is applied) at such a time that there is an accelerating voltage across this gap. The faster the magnetic field is increased, the greater is this accelerating voltage and hence the greater is the gain in energy for each orbit of the electron. Provided that the radio-frequency voltage across the gap is large enough and the change in magnetic field not too great, the electron cannot get out of step with the accelerating radio-frequency voltage.

The term "synchro-cyclotron" has been applied to another version of the synchrotron, in which the magnetic field is kept at a fixed value and the radio frequency is varied in such a way as to keep the machine in synchronism as the mass of the particle (proton, deuteron, or alpha particle) increases. In a sense the synchro-cyclotron is a half-breed between the cyclotron and the synchrotron. Several of these machines are now under construction, ranging up to 450MeV. In a third type of synchrotron simultaneous variation of the magnetic field and the radio frequency makes possible acceleration of protons to extremely high energies. One equipment of this kind is expected to produce 6000MeV.

The M.I.T. Synchrotron

The M.I.T. synchrotron has a peak magnetic field of 12,000 gauss at an orbit radius of 1m, which corresponds to a peak energy of 350MeV. The magnetic field is produced in a 3in gap requiring a peak magnetomotive force of 81,000A turns. The magnet (Fig. 2) weighs 55 tons and consists of twenty-four essentially identical "C"-shaped sections, the poles of the magnet ("C"-shaped) facing inwards. Each section contains a 10in stack of 14 mil. highly oriented transformer steel. This relatively small size was made possible by limiting the maximum duty cycle of the machine to 10 per cent. Under these conditions the copper windings were reduced to a total cross-sectional area of only 80 square inches; the windings consisting of eleven conductors in parallel, each having sixty-one strands. Each strand is coated with enamel and each conductor with a double layer of baked, varnished

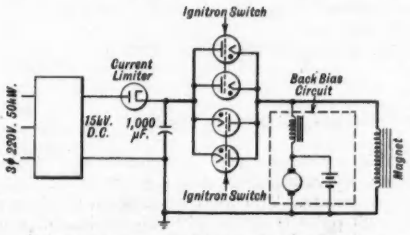

FIG. 3—SIMPLIFIED MAGNET EXCITATION CIRCUIT

cambric. This procedure is required to reduce the eddy current losses resulting from the large fringing flux of the 3in magnet gap.

The magnet is excited cyclically. The schematic is illustrated in Fig. 3. Power is taken from the mains at three-phase, 220V. A three-phase, full-wave rectifier converts it to direct current at 15kV. The direct current is used through a high vacuum diode (ML-101), to charge the main capacitor bank, which has a rating of 1000 microfarads at 15kV peak. The diode serves to limit current drain on the rectifier. The capacitor bank is connected to the magnet through an electronic switch, consisting of four GL-506 ignitrons. Each ignitron is rated 20kV peak inverse, 4000A peak surge. The inductance and the main capacitor bank capacitance are designed to resonate at roughly 60 c/s. The voltage wave during a single cycle of operation is illustrated at the top of Fig. 4. The cycle is initiated by a triggering pulse to the leading pair of ignitrons. The striking of the ignitrons raises the voltage on the magnet from zero to 15kV. The next interval consists of a half cycle of a 60 c/s sine wave, except that at the beginning and end a small transient appears. This transient

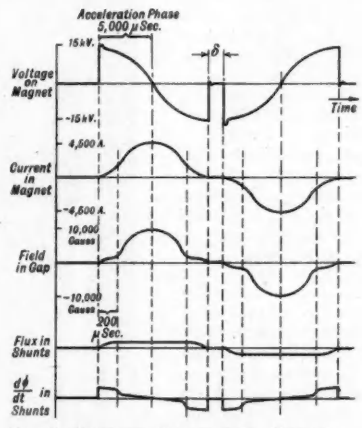

FIG. 4—MAGNET EXCITATION CURVES

results from the distributed inductance of the busbars in the capacitor magnetic circuit. These transients can actually result in doubling of the voltage with ensuing damage to the ignitrons and possible damage and breakdown between layers of the magnet windings. Such rapid and large transients are prevented by damping circuits placed on the magnet and across the ignitrons. They are not shown in the diagram, Fig. 3. At the end of the half-cycle the capacitor is charged in the reverse direction and the current drain on the rectifier is limited by the current limiter tubes. Were these not present the rectifier would be shorted as it would be looking into the very large capacitor bank with a 30kV difference in potential. After the completion of the first half-cycle and a small interval of time δ the trailing pair of ignitrons is ignited and the capacitor bank is recharged in the original sense. The time interval δ is purposely included to allow for the variations in the resonant frequency of the magnet capacitor circuit with temperature and with maximum current. It is to be noted that the capacitors are now recharged to their original value less the losses incurred during the cycle, which represents about 5 per cent of the total energy stored in the capacitors. These losses are made up by the rectifier. The capacitors are essentially identical to those sold by the General Electric Company for power factor correction. In the present application, however, the voltage rating on the capacitor units was higher (but still below the so-called "corona point"), giving approximately three times the energy storage. The increase was made possible by the fact that in 60 c/s continuous operation the power rating on the capacitor is established by the heating at the centre of the capacitor, with consequent raising of dielectric losses. Obviously, using these capacitors at the lower duty cycle reduces the cost of energy storage by a factor of ⅓. In passing, it may be noted that when these capacitors are limited to 10 per cent duty cycle they must be externally heated in cold weather. The 33⅓ per cent factor for pyranol is true at temperatures above 50 deg. Fah. Below this temperature the power losses are too high for satisfactory operation. Consequently, since the M.I.T. synchrotron may be operated at any arbitrarily slow rate, say one per minute, it is necessary to supply external heating for the capacitors.

The current waveform is shown in Fig. 4. It is to be noted that the waveform consists roughly of a 30 c/s and 60 c/s component. The 30 c/s component at low currents is caused by the presence of magnetic flux bars (shunts), which carry the betatron flux. These flux bars begin saturating at about 200 microseconds after the initiation of the cycle. With saturated flux bars the magnet has an inductance corresponding to about 60 c/s. The field in the gap shown in the third graph essentially follows the current in the magnet, whereas the flux in the betatron flux bars (shunts) shown in Fig. 4 is saturated for the major part of the cycle. The energy required to supply the flux in the betatron bars is a very small percentage of the total energy. The bottom curve shows approximately the voltage per turn at the orbit, resulting from the betatron action of the flux bars. It is to be noted that after about 200 microseconds the voltage is inadequate to accelerate the electrons as required by the betatron condition; namely, that the average flux density within the orbit should be approximately twice the flux density at the orbit. It is necessary for the radio frequency oscillator to be turned on before this betatron condition collapses. Indeed, it is necessary in the design of this machine to investigate very closely the limits to which this betatron condition is satisfied up to the time when the radio frequency oscillator can be turned on. This is most easily done by bucking the voltage induced in a turn at the orbit against the voltage induced in a bifilar winding at the orbit connected through a resistance network in such a way that a balancing of the induced voltages represents satisfying the betatron condition. Fig. 5 is a reproduction of an oscillograph record. The dotted lines indicate the limits beyond which the betatron condition cannot be satisfied without the electrons striking the walls of the tube. Obviously, if there is too much flux at the centre the electrons will spiral outward. Conversely, if there is too much flux at the ends the electrons will spiral inward. The figure indicates that in the beginning there is a large transient because of insufficient flux at the centre, followed by a region in which the betatron condition is satisfied. The initial transient is attributed to the transient eddy current built up in the laminations of the magnet. It cannot be overcome by design except by decreasing the thickness of the laminations, with consequent exorbitant increase in cost. It follows that the electrons must be injected at an energy high enough to permit the decay of the transient or else the transient must be moved to essentially nega-

tive time by starting the magnet with a net negative magnetic field. The latter procedure was adopted. Fig. 3 shows within dotted lines a "back bias circuit," comprising an inductance in series with a d.c. generator and battery and shunt. This produces a d.c. component through the magnet so that the transient

FIG. 5—OSCILLOGRAPHIC RECORD ILLUSTRATING BETATRON BALANCE

shown in Fig. 5 has decayed by the time injection takes place at 8 gauss.

During the acceleration phase, corresponding to the first quarter cycle shown in Fig. 4, the electrons make approximately 100,000 orbits. These orbits are stable in the vertical direction and radial direction if the magnetic field at the orbit falls off with radius as $B=B_0\left(\frac{r_0}{r}\right)^n$, where n must be between the values of zero and 1. The M.I.T. synchrotron was designed to have a value of $n=\frac{3}{4}$. Under these conditions the radial oscillation period is twice the rotational frequency. The shape of the poles was based on d.c. model work. The synchrotron magnet, therefore, should exhibit correct radial dependence of the field at high currents. Remanent flux, eddy currents and hysteresis curves, combined with the transient effect noted above, all conspire to affect the value of n at low magnetic fields. These effects were compensated by placing above and below the acceleration tube flat windings consisting of nine turns spaced 1in apart. The current through each of these could be independently varied. Power is supplied from the mains and the magnet cycle is so synchronised that the voltage wave illustrated in Fig. 4 appears at the instant the mains voltage goes through a maximum. The corrections in these trimming coils are only of the order of a fraction of an ampere turn each, compared to the value of nearly a hundred thousand ampere turns in the main windings. Azimuthal corrections on the magnetic field have also to be applied to allow for variations in eddy currents and hysteresis in the twenty-four sections of the magnet. These correction windings were applied to each magnet section separately and so connected to the mains that small corrections proportional to the sine of the azimuthal angle, cosine of the azimuthal angle, and of the sine and cosines of twice the azimuthal angle were made. Operation of the machine without final adjustments of these trimmers cannot be accomplished. The interesting fact is that once these adjustments are established they do not vary from day to day.

The accelerating tube is made in twelve sections of a specially prepared slip-cast steatite, having a dielectric constant of 9·0. The ends of the sections are cut and ground and fastened together with a thermo-plastic. The tube is vacuum tight and a vacuum of 2×10^{-6}mm of mercury is maintained during operation of the synchrotron. One section of the tube is coated on the inside and outside with a Du Pont silver coating and acts as a quarter-wave line cavity at 46·5 Mc/s. The peak voltage across the open end of the cavity required to accelerate electrons without loss is approximately 5000V.

The electrons on reaching the energy of 350MeV may be forced to strike a tungsten target by any one of three methods: (1) by turning the oscillator off before the maximum magnetic field is reached, resulting in an X-ray pulse approximately 10 microseconds long; (2) by shifting the orbit sidewise rapidly by means of ejection coils, resulting in an X-ray pulse approximately 1 microsecond long; (3) by amplitude modulating the cavity voltage after the maximum magnetic field has been reached, in such a way that the electrons are stripped off gradually by the target in the beam, resulting in an X-ray pulse approximately 1000 microseconds long.

The first method is generally used for cloud chamber work and nuclear emulsion plate studies. The second method is generally adaptable for the detection of mesons by the decay of electrons. The third method is used for counting experiments, where maximum statistics are required. In all cases the X-ray output is extremely well collimated, the beam being approximately 0·2 deg. wide at half power points. The total strength in the beam in each pulse is essentially independent of the method of ejection. Under best conditions the ionisation measured in a Victoreen thimble chamber, surrounded by ½in of lead and placed 2½m from the target, gives a measured output of approximately 500 milliroentgens per pulse. With the present restrictions on power available in the power mains, the maximum repetition rate in the machine is two pulses per second, giving a maximum dosage of 720 roentgens per hour at 2½m. An exposure of four hours is required for photographic emulsion plates placed next to a carbon scatterer to give a meson production of the order of 100 mesons per plate.

It is too early to predict what results will come from accelerators of the type of the M.I.T. synchrotron in the 350MeV range. Already much has been done, such as the measurement of the decay of the π meson ($1\cdot\times10^{-8}$ seconds), the measurement of the mass of the π and μ meson, the measurement of the relative abundance of positive and negative mesons, the detection of neutral mesons, the measurement of the excitation of various nuclei, &c. It is sufficient to point out that the energy storage in each electron in the synchrotron results in a seven hundred-fold increase in the mass of the electrons with an energy storage of twice that of uranium fission.

ACKNOWLEDGMENT

The material for this article was provided by the Department of Electrical Engineering, Massachusetts Institute of Technology, where four names are prominently associated with the M.I.T. synchrotron: Professor I. A. Getting, in charge of the whole project; Mr. J. S. Clark, in charge of magnet design and operation; Professor J. E. Thomas, Jr., in charge of radio frequency and detection equipment; Mr. I. G. Swope, in charge of power equipment.

The Physical Society's Exhibition

No. I

MORE than 150 exhibitors are participating in the thirty-fifth exhibition of scientific instruments and apparatus organised by the Physical Society. The exhibition is being opened to-day, Friday, April 6th, at 10 a.m., by Professor L. F. Bates, President of the Physical Society, and it will remain open daily, excluding Sunday, until Wednesday, April 11th, admission being by ticket only. The number of exhibitors has increased by more than 10 per cent compared with last year, and the available accommodation has been increased substantially by making use of the Huxley Building, in Exhibition Road, to supplement the resources of the main building, Imperial College, in Imperial Institute Road.

An interesting innovation this year is that French Government Research is represented at the exhibition; there are contributions from three organisations — Centre Nationale de la Recherche Scientifique, Commissariat à l'Energie Atomique and Office National d'Etudes et de Recherches Aeronautique.

During the period of the exhibition a series of discourses will be delivered in the large Chemistry Lecture Theatre in the main building. To-day, Friday, at 6.15 p.m., Dr. G. E. R. Deacon, of the Admiralty Research Laboratory, Teddington, will discuss electric currents in the sea. This subject is of interest in view of the possibility of obtaining quantitative information about tidal streams and other water movements by recording horizontal potential gradients induced by movement through the earth's magnetic field.

On Monday, April 9th, at 6.15 p.m., Dr. D. McKie, of University College, London, will lecture on the "Age of Newton." On Tuesday, at the same time, Dr. F. P. Bowden, Department of Physical Chemistry, Cambridge, will lecture on the friction of metals and non-metals, and the influence of surface films. Finally, on Wednesday, April 11th, at 3.45 p.m., Dr. C. A. Sayce, of the National Physical

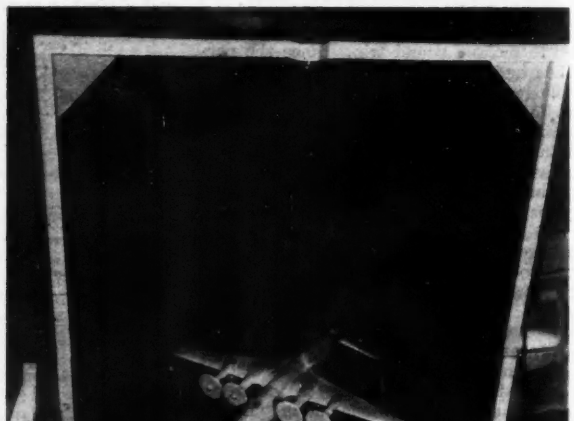

FIG. 1—MODEL RIG FOR AERIAL RADIATION RECORDING—FERRANTI

Laboratory, will describe and illustrate some of the work of the Light Division at the N.P.L.

Referring to the exhibition itself, we give a brief description, in the following paragraphs, of a few of the many exhibits that may appeal to engineers.

Ferranti, Ltd.

An interesting new exhibit shown by Ferranti, Ltd., Hollinwood, Lancs, is a recorder, which uses scale models to plot the radiation characteristics of aircraft aerials with less expenditure of time and effort than that required for full-scale measurements.

In an aircraft aerial the radiation pattern may be appreciably modified by the presence of the aircraft, especially when aircraft size exceeds wavelength. The shape and positioning of the wings, engine nacelles, tailplane, &c., and asymmetry in the fore-and-aft direction all contribute in varying degrees to produce a distorted radiation diagram. Thus, since the complex character of the aircraft surface must be taken into account, mathematical computation of aerial behaviour becomes very difficult. Qualitative forecasts can be made in most cases, but they are of little value, for example, in determining optimum aerial siting for a particular application, and precise results can only be obtained by actual measurement. Experiment using a "life-size" aeroplane, however, is generally impracticable. Measurements made with the aircraft grounded are ruled out, since stray reflections must be avoided and a truly three-dimensional family of radiation patterns is desired. On the other hand, flight tests would be time consuming, expensive and of doubtful accuracy.

These difficulties can be overcome by using models, reducing both aircraft dimensions and operating wavelength by the same scaling factor. The radiation pattern recorder that is exhibited was designed under Ministry of Supply contract.

As initially developed, the equipment is intended to cater for the aircraft installation of L-band aerials (30cm) in connection with the Ferranti distance measuring equipment. By using a scaling factor of 24 the modelling wavelength falls in K-band (1·25cm) and a typical passenger aircraft has a scaled wing span of, say, 4ft to 6ft. The yoke suspending the model (shown in Fig. 1) allows both principal plane (great circle) and small circle patterns to be taken. The model acts as a transmitter, but results thus obtained are equally valid whether the full-scale aerial is to be used as a transmitting or as a receiving element. The receiver is a superheterodyne set with an intermediate frequency of 45 Mc/s. This method yields several advantages. First, the recorder can be used over a wide range of wavelengths simply by changing either the scaling factor or the receiver head, or both. Secondly, a stable high-gain receiver becomes permissible. The working range can then be made large (up to 1000 wavelengths at K-band) despite limited transmitter power. Thirdly, a piston attenuator can be introduced, which provides a high degree of accuracy and a power scale which is linear in db.

The recording equipment (Fig. 2) consists essentially of two separate servomechanisms. The first, the rotational system, produces motion of the plotting table in sympathy with the remotely controlled rotation of the aircraft model. The second, the translational system, determines the deflection of a pen according to the instantaneous value of the power radiated by the aerial under test. Plots may be taken either in Cartesian or polar co-ordinates, for a maximum variation in signal power of 40 db, and for a writing speed normally between 1·5 minutes and 2 minutes per pattern.

Another Ferranti exhibit is a new seven-range clip-on ammeter, specially designed for use on porcelain-clad fuses which are too large for the normal clip-on instrument. It will accommodate conductors up to 4in in diameter. The ammeter comprises a split-core current transformer with a large centre-opening core and a 2½in dial rectifier instrument combined in a black bakelite case with range selector switch. The magnetic joints of the core are self aligning under the influence of a powerful spring, thus ensuring consistent accuracy of readings. Seven ranges of measurement up to a maximum of 1000A a.c. are provided. The instrument is suitable for use on frequencies of 50–70 c/s., but can be calibrated at a particular frequency, if desired. The core is fully insulated and can be used with safety on bare conductors up to 600V a.c. The range selector switch is conveniently placed for thumb operation and the whole instrument is well balanced and easy to manipulate with one hand.

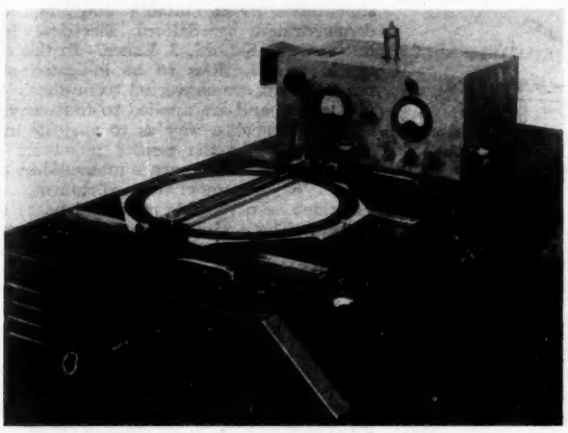

Fig. 2—Radiation Recorder—Ferranti

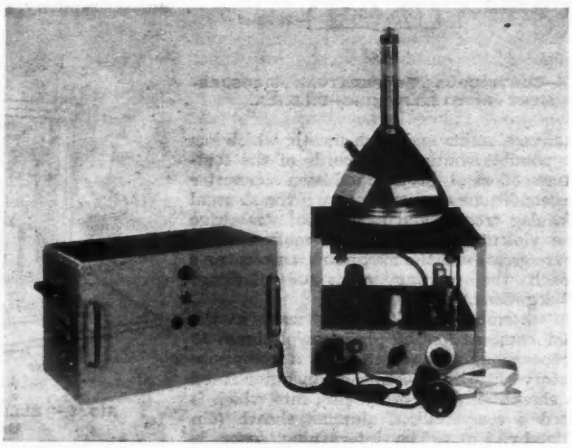

Fig. 3—Measurement of Thin Metal Films—G.E.C.

G.E.C. Research Laboratories

Among the exhibits demonstrated by the research laboratories of the General Electric Company, Ltd., is apparatus which has been designed for the rapid checking and control of the thickness of thin metal films on insulating surfaces, such as the aluminium backing on a cathode ray tube screen (Fig. 3). Briefly, the apparatus consists of an inductance coil, which forms part of the tuned circuit of a thermionic oscillator, the frequency of oscillation being determined partly by the introduction of the metal film whose thickness is being measured. To obtain adequate sensitivity in the determination of this frequency the output of the oscillator is caused to beat with the output from a standard oscillator. The standard oscillator frequency is set at a value that gives zero beat frequency when the variable oscillator assumes a frequency corresponding to the required thickness of metal on the screen of the cathode ray tube. Then, in checking a batch of tubes, any departure from the desired film thickness appears as a beat frequency in the apparatus. Automatic control of the thickness of metal deposited by vacuum evaporation techniques can be effected by incorporating suitable frequency selection circuits together with relays to control the temperature of the evaporating source.

The G.E.C. research laboratories are also demonstrating some of the advantages of barium titanate resonator elements compared with elements made from piezo-electric materials such as quartz. Barium titanate, which has a high permittivity, is conveniently prepared as polycrystalline ceramic. This material is electrostrictive, which means that mechanical resonances can be excited in the ceramic by applying suitable alternating electric fields between electrodes formed on the element.

One advantage of barium titanate resonator elements is the high electromechanical coupling factor of the ceramic, which makes it suitable for use as a transducer capable of handling large outputs of mechanical power. Further, it is comparatively simple to prepare the resonator element, because the ceramic is polycrystalline and it is therefore unnecessary to prepare the element by cutting it with respect to any preferred orientation. Instead, all that is required is to polarise the element by a strong unidirectional electric field.

Evershed and Vignoles, Ltd.

Among the instruments exhibited by Evershed and Vignoles, Ltd., Chiswick, London, W.4, is a new form of quick-response recorder, which is designed to follow frequencies up to 10 c/s, working from high-speed thermocouples or strain gauges. The new recording movement incorporates a two-phase induction motor giving a sensitivity of ±1millivolt direct current, instead of the moving coil movement in the instruments demonstrated at previous exhibitions, with a sensitivity of only ±10V direct current. In the new instrument variable damping is provided by a drag cup generator coupled to the movement.

The recorder, which is servo-operated, consists of a driving amplifier and a recording mechanism, mounted together in a portable aluminium case. The amplifier is controlled by the feed-back from a fine-wire, centre-tapped potentiometer which operates in conjunction with the moving system of the recorder. By winding the potentiometer with a very fine pitch a close approach to stepless control has been achieved.

The recording mechanism writes on a chart 3½in wide driven by a synchronous motor; a four-speed gearbox provides speeds of ½in, 1in, 3in and 6in per second, but other speeds can be made available. According to requirements, the instrument can be arranged either for side or centre zero, and the recorder is suitable for ink or "Teledeltos" chart recording. The equipment is designed to operate from a single-phase, 230V, 50 c/s supply.

Another instrument to be seen on the same stand is a "Megger" insulation tester, which is new in the sense that it has three voltage and six megohm ranges. In outward appearance this instrument is very similar to the ordinary "Series 1" instrument. The top of

the new test set, however, carries a six-position range switch, whereby tests can be carried out at 500V (ranges 0 to 50 and 3 to 10,000 megohms), 1000V (ranges 0 to 100 and 5 to 20,000 megohms) and 2500V (ranges 0 to 200 and 15 to 50,000 megohms).

British Iron and Steel Research Association

Three out of the four exhibits shown by the British Iron and Steel Research Association reflect the steel industry's increasing interest in continuous measurement of variables in industrial processes. The fourth is of more fundamental interest. One of the continuous measuring projects relates to steel making, one to steel strip rolling and the other to the multiple recording of a number of measurements.

Continuous temperature measurement in steel making is the subject of one of the exhibits. It consists of a thermocouple in its

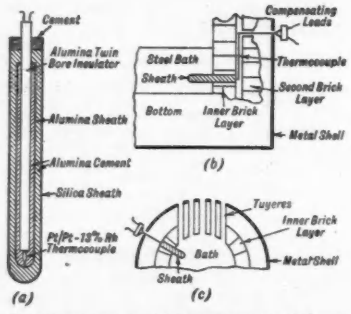

FIG. 4—CONTINUOUS TEMPERATURE MEASUREMENT IN STEELMAKING—B.I.S.R.A.

protective alumina and silica sheath, which has made possible continuous records of the temperature of steel in a side-blown converter where conditions are very severe; the thermal shock, slag erosion and mechanical stress due to the violent agitation of the molten metal bath are great, and the maximum temperatures approach the melting point of platinum (1773 deg. Cent.).

The thermo-couple (Fig. 4) used is the normal combination of platinum/platinum-13 per cent rhodium, protected by a composite refractory sheath consisting of an outer fused silica sheath (7in by ½in by ⅜in), into which is inserted a recrystallised alumina sheath (6in by ¼in by ⅜in). The intervening space is packed with dry alumina cement and the whole is sealed with a refractory fireclay cement. The two thermo-couple wires are kept separate by insertion in a twin-bore alumina insulator, which is inserted into the inner sheath and embedded in position with dry alumina cement. The refractory sheaths are mechanically supported and the heat is more readily conducted to the thermo-couple by the dry refractory packing.

During the lining of the vessel the thermo-couple is inserted about two-thirds of the way down the metal depth and about 9in from the tuyeres. One installation will give readings throughout nine consecutive "blows" of twenty minutes each, spread over a period of several hours.

Visitors to the B.I.S.R.A. stand can also see an instrument which has been developed for the continuous measurement of the width of hot strip as it leaves the rolls at up to 1200ft to 1800ft per minute. This measurement is particularly necessary in the manufacture of strip for tube making, when it is necessary to keep the strip width within small tolerances. The problem is complicated by high temperature of strip; high speed of movement of strip; lateral shake between guides; undesirability of mechanical contact with strip.

In the instrument exhibited a parallel beam of light is projected at right angles to the strip, one edge of which cuts off one side of the beam. The beam is then reflected twice at right angles, with one lateral inversion, and projected across the second edge of the strip, which cuts off the other side of the beam. After passing the two edges the residual beam width varies inversely as the strip width, and will be proportional to the total light flux carried (if the beam section is rectangular and the light distribution uniform), but will be unaffected by transverse movement of the strip within the limits of the beam.

The residual beam width is measured by balancing its total light flux against that carried by a comparison beam, from the same light source. The beams are chopped at source and are brought together on one photocell, which gives an a.c. output on unbalance. The electronic circuits operate a spiral shutter in the comparison beam, which moves to restore balance. The shutter position then measures strip width and the balancing system eliminates errors caused by variation in lamp brightness, amplifier gain or photocell sensitivity. Chopping at source eliminates the effect of radiation except from the light source. In trials the hot air from the strip will be removed by air jets to minimise refraction effects.

On its laboratory performance the instrument can detect width variations of ±0·005in, its range being ±0·1in and the permissible side shake 0·25in.

Elliott Brothers (London), Ltd.

Prominent among the exhibits shown by Elliott Brothers (London), Ltd., Lewisham, London, S.E.13, is the "Elliottel" remote indication and control system, which is a modification of the well-known Elliott Shotter system of remote indication. The main characteristics of the equipment are its mechanical simplicity, the absence of sliding contacts

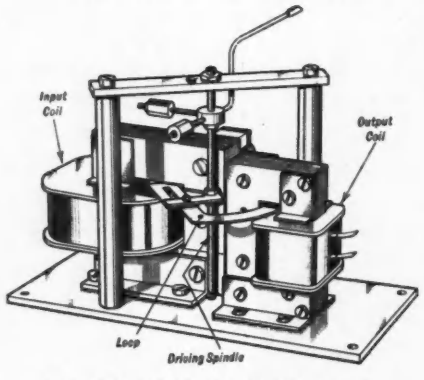

FIG. 5—"ELLIOTTEL" TRANSMITTER UNIT—ELLIOTT

or relays and the fact that the transmitting element imposes virtually no restraint on the originating movement. The apparatus is stated to be capable of transmitting indications over pilot wires about 25 miles long and is approved by the G.P.O. for use over Post Office lines.

The elements of the system are shown schematically in Fig. 6. Its main component is a transmitting element (Fig. 5), which embodies a variably coupled transformer. The input iron system is energised from a.c. mains through a voltage regulator and is variably coupled to the output system by a single-turn coil of high-conductivity material shaped like a distorted figure of eight, which is rotated by the originating movement. The larger of the two loops forming the "8" passes through the output iron system, while the other loop, known as the "reverse turn," crosses an air gap in the input iron system. Thus the input and output elements are linked electrically to an extent that depends on the angular position of the coupling coil. This coil is so shaped that it produces an output current proportional to the deflection imposed by the originating movement. If it is desired to summate the output of two or more transmitters, it is arranged that zero deflection of each transmitter gives zero output current. Temperature compensation is achieved by a magnetic shunt across the air gap of the energising coil.

The "Elliottel" transmitter can be mechanically coupled to a wide variety of measuring instruments, such as pressure gauges, flow meters, or wattmeters, or to other devices capable of producing rotary movement proportional to a physical quantity. Whatever the originating movement, the appropriate current proportional to the deflection is transmitted to the remote receiving element, which is essentially a milliameter. To suit individual requirements the receiver may take the form

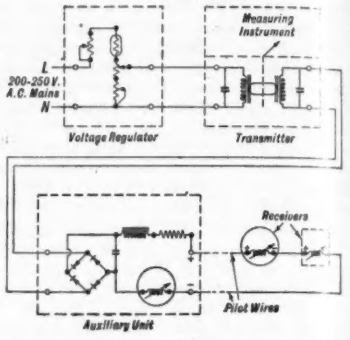

FIG. 6—"ELLIOTTEL" REMOTE INDICATION SYSTEM—ELLIOTT

of an indicator or a recorder which may be fitted with alarm contacts, if required. The equipment is very flexible; signals for the control of pump motors, for example, can be transmitted over the same pilot wires and telephony can be carried on simultaneously.

Salford Electrical Instruments, Ltd.

Another remote indicating system of considerable inherent stability and simplicity is demonstrated by Salford Electrical Instruments, Ltd., Salford, 3, Lancs. In this equipment the quantities to be indicated at the remote point are converted to mechanical displacements and are applied to the transmitter element in such a way as to vary its mutual inductance. At the remote indicating point this change of inductance is measured by a new design of dynamometer instrument, which functions as a variable ratio and phase transformer. The complete system of receiver and transmitter operates as an electrodynamic servomechanism and is inherently independent of mains voltage and frequency variations. The remote indicating properties of this arrangement are not confined to a single receiving instrument; a number of remote indicators can be coupled to a single transmitter, or a single indicator can be used to indicate the output of several transmitters. Indicating instruments with scale lengths of 100 deg. and 270 deg. have been designed for use with the transmitting equipment.

A second group of exhibits on this stand demonstrates the characteristics of the "Rotasol" semi-rotary drive mechanism, which consists of a high-torque, impulse-operated motor associated with a pawl and ratchet selector mechanism designed to give a unidirectional motor on the output shaft. The motor has a limited arc of rotation per impulse and was designed primarily for operating combinations of "Yaxley" or "Oak" switches. In this particular application the arc of rotation is limited to 30 deg. However, for other applications involving remote control apparatus for the operation of hydraulic valves the arc of rotation of the "Rotasol" can be considerably extended.

Three versions of the "Rotasol" type 2 have been developed to operate the miniature "Oak" ceramic switches. The Mark 1 mechanism is designed to operate continuously a load of four eleven-way single-outlet switch banks, or the equivalent. They can be stepped continuously through their twelve positions with impulses supplied from a standard Post Office dial. The Mark 2 mechanism is a single-stepping self-returning switch-operating motor and has a "hold" position, with low current consumption, to keep the switch in its operated condition. Loading of the switch is provided by two miniature "Oak" ceramic wafers, each containing four change-over contact circuits, one of which serves to switch in the hold-on coil, leaving seven available outlets for external use. The Mark 3 equipment differs from the Mark 1 only in having provision for rapid homing of

the banks to a datum position. The addition of a special end cap (with a set of heavy-duty interrupter springs) to the standard Mark 1 unit allows it to be used like a single-motion uniselector.

An exhibit of a very different kind is a transportable emergency lighting equipment incorporating a lamp, rectifier, selenium charging circuit and an Exide low-loss battery. The arrangement provides for taper charging the battery, the current falling away to about 50mA, so that a continual charge does not damage the lead plate cells. A small relay is built into the unit, whereby on mains failure the lamp is connected to the battery, providing instantaneous flood lighting. The lighting unit is approximately 16in long, 6in wide, and 11in high, without the lamp, which adds 8in to the overall height.

B.T.H. Research Laboratory

Some indication of the varied activities of the B.T.H. research laboratories, Rugby, is given by the exhibits to be seen on this stand. The equipment shown includes an X-ray texture mapping camera, a 100kV (r.m.s.) capacity divider, infra-red detectors, germanium crystal diodes and a high-voltage ignitron.

The ignitron is a type "BK 56" water-cooled unit (Fig. 7) for power rectification, its rating being: anode voltage (forward and

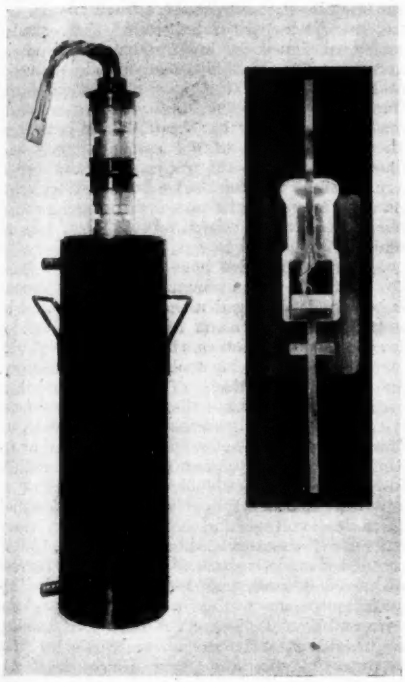

Fig. 7—Water Cooled Ignitron (Left) and Sectioned Model of Germanium Crystal Diode (Right)

inverse), 20kV; anode current average (continuous), 150A; anode current (instantaneous), 900A. Control of the ignitron is exercised not only by the ignitor, but also by the shield and control grids, and a third grid is included for distribution of voltage stress. For power rectification a group of these valves can be connected in standard circuits. The valve can also be used as a switch to control current pulses up to peak values of over 1500A in special high-voltage applications. It is being used for this kind of duty in Glasgow University's 375MeV synchrotron, its function being to control the supply of current pulses to the magnet windings at a voltage of 17kV.

The company is also showing an exhibit presenting recent advances in the application of germanium crystals. The photograph reproduced in Fig. 7 is of a sectioned model, about 4½ times full size, as shown, of a germanium crystal diode in a moulded container. To simplify the manufacture of the unit the case is made from a thermo-setting synthetic resin moulding material.

Compared with the metallic oxide rectifier the germanium rectifier has a much greater power-handling capacity for a given size, and the point contact is stated to offer a much better frequency response due to its lower contact capacitance. Accordingly, the germanium rectifier is particularly suitable for many high-frequency applications. It is rated at 80V (peak value) maximum reverse voltage, with a maximum continuous input current of 50mA and a maximum peak input current of 400mA, which is limited to one second duration; the average total capacitance of the unit is given as 0·5μF. The manufacturers state that, provided the voltage and current ratings are not exceeded, an operating life of several thousand hours can be expected.

The central exhibit on the stand is a texture or preferred-orientation moving film camera, which is designed for the study of silicon iron sheet, having varying grain size and thickness, using reflections and molybdenum radiation. The sample consists of a column of discs mounted on a screw at right-angles to the X-ray beam, and the film performs a traverse at right-angles to both with a sudden fly-back after each 180 deg. rotation of the screw. A useful characteristic of the system is that the photographic record can be used directly as the equivalent of the conventional plotted pole figure. The photograph forms a map of the reference sphere, but, instead of the usual stereographic projection the map that is obtained closely resembles a Mercator's projection.

(To be continued)

Technical Advances and Trends in Electric Traction*

Since 1928 there have been no outstanding advances in the principles of design and construction of electric traction plant and equipment, partly due, no doubt, to pre-occupations with other matters from 1939 to the present time. Certain developments have taken place, but some of these, although important in themselves, have been rather in matters of detail and are not such as to have any material bearing on the recommendations of the Pringle Committee.

The Mercury-Arc Rectifier

The development which may perhaps be considered the most important is the perfection of the mercury-arc rectifier as a means of transforming three-phase alternating current at the standard industrial frequency to direct current at any desired voltage. This has removed one of the disadvantages of the 3000V d.c. system, which previously required substations equipped with motor generators, consisting of synchronous three-phase motors coupled to pairs of 1500V generators connected in series. Not only has the mercury-arc rectifier effected a marked reduction in first cost, but, even more important, it has raised the conversion efficiency at 3000V from about 85 per cent to 95 per cent and has reduced the cost of maintenance. Similar improvements, though to a lesser degree, are obtained by substituting rectifiers for the rotary convertors previously provided in 750V and 1500V substations.

The use of mercury-arc rectifiers has been extended experimentally to the single-phase system of electrification. By a special arrangement of grid control a pair of rectifiers can be made to convert three-phase alternating current at any frequency, and in particular at the frequency of the general and industrial supply, to single-phase alternating current at a low frequency, i.e., 15 or 16⅔ or 25 c/s, for the power requirements of electric traction. The effect of this development is to enable power for single-phase a.c. railways to be taken from the general or national supply system by means of high-efficiency substations containing no main rotating plant, instead of frequency-changing motor generators having a service efficiency of not more than 85 per cent.

An experimental substation of this type was installed at Basle in 1937 for the transfer of power in either direction between two systems of different frequency, viz., 50 and 16⅔ c/s. The nominal capacity of the rectifiers is 3600kVA at 0·7 power factor, with one-minute overloads of 6000kVA. Operation has proved technically practicable, but owing to the sensitivity of the control there have been many difficulties. In the first five years, back-fires in the rectifiers were frequent, at the rate of twenty per month. These have been reduced during the last two or three years, by adjustment of the grid control, to two or three per month. The sensitivity of the control arises mainly from the varying power factor of the transferred load, and difficulties of operation are inherent unless the power factor is maintained at or near unity by some external means, such as a supply to the network from an independent source of wattless kilovolt-amperes.

The grid control apparatus is elaborate and bulky, and the overall cost of the substation is high, partly on this account and partly owing to the necessity to provide both step-up and step-down transformers. It is estimated that the cost of such a substation is slightly above that of a motor generator substation of the same capacity. All things considered, it seems doubtful at this stage whether any appreciable overall advantage is to be expected from the use of conversion plant of this type as a means of obtaining low-frequency power for traction purposes from a 50-cycle supply network.

A further use has been found for rectifiers in the electrical equipment of tractors on the single-phase a.c. system. By this means power taken from the overhead line can be converted on the locomotive or motor coach to direct current for supply to d.c. traction motors. The arrangement is not limited to any definite voltages of supply or delivery, nor to any particular a.c. frequency; it is therefore well adapted to the use of alternating current at the standard frequency without the necessity for frequency-changing substations.

An example of this development is to be seen in the experimental installation on the Höllentalbahn, described more fully below. Two of the four locomotives provided for this experiment are equipped with mercury-arc rectifiers; on one the supply of direct current to the driving motors is regulated by grid control of the rectifier, on the other by varying the tappings in the secondary winding of the step-down transformer. With both methods there is a liability to the production of harmonics in the a.c. supply line, this objectionable feature being more marked if the variable voltage is obtained by grid control.

In July, 1949, the Pennsylvania Railroad put into service on their suburban lines round Philadelphia an experimental motor coach equipped with two standard 225 h.p. d.c. motors supplied with power from the 11,000V single-phase overhead line through a group of four ignitron tubes (single-anode, mercury-arc rectifiers).

The direct current produced by rectification is a uni-directional current with a superimposed alternating current or ripple. The amplitude of the ripple can be controlled by the use of reactors in the main d.c. circuit, and during the experimental running has been limited to 33 per cent of the average current. With this limitation the motors have operated satisfactorily without overheating or sparking at the commutators.

The arrangement, however, necessarily gives rise to harmonics of considerable amplitude in the single-phase alternating current in the overhead line which may cause serious interference in parallel communication circuits. The extent of this interference is being studied by those concerned. Tests are not yet completed, but they indicate that on a 25-cycle system practical filters can be produced which will keep the interference within tolerable limits.

Considerable importance is attached to these experiments in view of the advantages to be gained from the use of standard d.c. motors, especially in the cost of maintenance, and the possibility, not yet proved, however, that for future electrification schemes the same inherent

* Abstracted from Report on "Electrification of Railways," British Transport Commission, 1951. Price 7s. 6d.

advantages may be realised on a high-voltage single-phase, a.c. system at the standard frequency of 50 or 60 cycles. The equipments could, of course, be designed for operation also on adjacent sections electrified on the d.c. system.

Flywheel Locomotives

Reference has already been made to an important advance in the design of electric locomotives for use on low-voltage conductor rail systems. The gaps in the conductor rails at junctions, turn-outs and level crossings can be bridged by multiple-unit trains, but not always by single locomotives. Trains hauled by electric locomotives of normal type on the conductor rail system would be subject to sudden interruption and restoration of drawbar pull at such points, and there is also the possibility of a locomotive being stalled at a gap. The former feature is particularly objectionable with freight trains of loose-coupled wagons. For Southern Region traffic, three locomotives have been built with motor generator sets, each set including a heavy flywheel, the kinetic energy of which is sufficient to carry the train over a gap without sudden cessation of the drawbar pull. Locomotives to this design are rather more expensive and less efficient electrically than those of the normal design with series-parallel resistor control. They have proved successful, however, in meeting requirements in the Southern Region, but it is very doubtful whether the same solution would be adequate to prevent locomotives hauling heavy mineral trains at slow speed from stalling on steep gradients over track lay-outs with lengthy gaps. In such conditions it would seem essential to provide a short section of overhead line at the same voltage and to equip the locomotives with pantographs.

Single-Phase Low-Frequency Traction Motors

Considerable improvement has been made in the design of single-phase, low-frequency commutator motors for railway traction, resulting in increased output in relation to weight, a higher standard of performance and lower cost of maintenance.

The Single-Phase 50-Cycle System

A development, which may prove to be of considerable importance in its influence on the future of railway electrification, is the experiment started on the Höllentalbahn in 1936 by the Deutsche Reichsbahn. This consists of the equipment of the section of line, 50km in length, from Freiburg to Seebrugg, including 7·2km of 1 in 18 gradient, on the single-phase, 50-cycle a.c. system, the line voltage being 20kV.

A feature of this experiment is the use of four locomotives specially designed for operation on a 50-cycle system. In order to explore the operating possibilities of the system, the four locomotives were built to different designs and supplied by different manufacturers. A comparison of these designs under working conditions was therefore feasible, and valuable experience has been gained by the regular operation of normal traffic in the course of the last thirteen years.

The line equipment does not differ materially in design from that in use on other sections electrified on the single-phase a.c. system. It is fed from a single substation situated at Titisee, not far from the mid-point of the section, supply being taken at 110kV, three-phase, 50 cycles, from the Forbach hydro-electric station of the Strasbourg Power Company and transmitted about 60 miles to Titisee. At the substation the power was originally transformed to 20kV, two-phase, by Scott-connected transformers, the Titisee-Freiburg section being fed from one phase and the Titisee-Seebrugg section from the other phase. Subsequently, the Scott connection of the transformers was considered unnecessary, and the whole section is now fed from one phase of the three-phase supply. The intention in using two distinct supplies for the different parts of the section was to reduce as much as practicable the unbalanced load on the three-phase power system when only one phase is utilised. In the special circumstances of this installation the "out-of-balance" was found to be within tolerable limits.

Each of the four locomotives has a capacity of about 2300 h.p., and the principal features of the different designs are as follows:—The locomotive supplied by Siemens-Schuckert is equipped with four pairs of commutator type, 50-cycle motors, each pair being geared to one axle of the two bogies. The Brown Boveri locomotive contains four d.c. motors and a mercury-arc rectifier which takes power at a varying voltage from the step-down transformer. The locomotive of the Allgemeine Elektrizitäts Gesellschaft also has a mercury-arc rectifier taking power from a step-down transformer, but the supply to the motors is regulated by grid control of the rectifier. The Krupp locomotive is on the "Kando" system, to which reference has been made (The Engineer, March 30th, page 413).

The first three of these locomotives are arranged for electric-rheostatic braking. Experience with all four locomotives has proved their practicability for the service required; the maintenance cost, after initial teething troubles, has been reasonably satisfactory. The general view is that the first two, namely, those by Siemens-Schuckert and Brown Boveri, are in some respects preferable to the other two. The others, using respectively a grid-controlled rectifier and a frequency changer with three-phase motors, are considered rather complicated and would not be repeated in any future installations on the same system. As between the first two, the maintenance cost of the Brown Boveri locomotive with d.c. motors and a rectifier is rather less than that of the Siemens-Schuckert locomotive.

It is pointed out that better results could probably be obtained now with more modern single-phase commutator motors, those on the Siemens-Schuckert locomotive having been developed as early as 1934. Nevertheless, the engineers of the Deutsche Bundesbahn consider that there has not yet been sufficient experience with this installation to justify the adoption of the single-phase, 50-cycle a.c. system on a large scale in future electrification schemes.

Experiments on French National Railways

The experimental installation on the Höllentalbahn has been followed by a recent decision of the French National Railways to carry out a similar experiment with up-to-date single-phase, 50-cycle locomotives on the line from Aix-les-Bains to La Roche-sur-Foron, a section 55 miles in length. The purpose of this experiment is twofold; first, to find the least expensive system for the electrification of branch lines which it would not be economical to electrify on the 1500V d.c. system in use on the main lines south of Paris, and, secondly, to ascertain whether the same system offers sufficient advantage over the 1500V d.c. system for the electrification of the main and branch lines in the north and east of France. The justification for embarking on this experiment is that the overall costs of electrification on this system, under the conditions obtaining on the French railways, are expected to be materially lower than on the 1500V d.c. system, due to the reduction in the cost of the substations, feeders and contact lines, in spite of the increase in capital charges and maintenance expenses of locomotives which, for equal service, are estimated at about 30 per cent.

Three prototype locomotives have been ordered, one each from the Oerlikon, the Als-Thom and the Schneider-Westinghouse Companies. The first two are to be equipped with single-phase, 50-cycle commutator type motors made by the Oerlikon Company; the third with d.c. motors fed from a motor generator. It is interesting to note that it is not intended to experiment with any form of locomotive equipped with a mercury-arc rectifier.

The locomotives to be supplied by the Oerlikon and Als-Thom Companies will be of the C_0-C_0 type, i.e., each will have two three-axle bogies, equipped with six motors, having an aggregate capacity on the continuous rating of 3000 to 3500 h.p. Power will be taken from a 20kV overhead line, and will be stepped down to 230V at the motor terminals. Operation will be controlled by varying the voltage through tappings on the transformer windings. Both locomotives will be provided with motor generator sets to enable them to operate on tracks equipped with 1500V d.c. lines at a reduced output sufficient for station duties. The mechanical design will be similar to that of the 1500V, 4350 h.p. C_0-C_0 locomotive recently brought into service on the Paris-Bordeaux line. The capacity will be about 20 per cent less than that of the 1500V locomotive, but the weight will be rather higher at 114 tons compared with 101 tons.

The locomotive to be supplied by the Schneider-Westinghouse Company will be of the B_0-B_0-B_0 type, i.e., it will have three two-axle bogies equipped with six 675V d.c. motors with an aggregate capacity of 3000 h.p. The motors will be supplied at a voltage varying between 0 and 800 from an asynchronous motor generator, and control equipment is provided to enable the locomotive to operate at full power either on 20kV alternating current or on 1500V direct current. Provision is also made for regeneration, the motor of the motor generator set acting as an asynchronous generator.

Of the different types of equipment on the 50-cycle a.c. system, the simplest is that which includes only 50-cycle commutator type motors supplied with power at a variable voltage from the step-down transformer. Such motors are necessarily larger and heavier than similar motors designed for low-frequency alternating current. For example, the outside diameter and weight of a 750kW locomotive type motor for a 50-cycle system, according to a recent design, are greater by about 60 per cent than those of a motor of the same capacity and characteristics for 16⅔ cycles. The number of brush sets is also considerably increased, namely, twenty-eight sets at 4in spacing round the commutator, compared with ten sets at 6in spacing.

Motors of smaller horsepower can be built to suit the requirements of multiple-unit suburban trains, and although they would be larger than equivalent low-frequency a.c. or low-voltage d.c. motors, there is no reason why they should not be technically satisfactory. In the present stage of development their larger diameter makes them unsuitable for use with small driving wheels—for example, of 36in diameter. This might affect their availability for the equipment of coaches with a low floor, such as double-deck coaches.

All single-phase, 50-cycle motors are designed for a low voltage and correspondingly heavy current. For example, the voltage of the 750kW motor referred to above is 168 and the current about 5000A, whereas for a comparable 16⅔-cycle motor the voltage would be 440 and the current about 1900A. It is the usual practice to provide forced ventilation by means of a separate blower, and it is desirable, if not essential, to employ some form of elastic connection between the armature and the axle to which it is geared.

Other Recent Developments

Reference may be made to other recent advances in electric traction technique, but these again have been rather in matters of detail, and are not such as to have any material influence on the choice of electrical system, namely:

(i) Improved designs have been evolved for auxiliary machines forming part of the electrical equipment of motor coaches and locomotives, such as auxiliary motor generators for 3000V direct current.

(ii) The improved design of d.c. railway motors has resulted in a higher power output per unit weight of material, and improved insulation methods and materials have been employed with consequent reduction of maintenance costs.

(iii) D.c. motors can now be designed with a wider range of speed and power variation by field control; such motors are useful for general-purpose locomotives.

(iv) Several forms of rotating d.c. voltage transformer, taking current from the line and delivering current at a variable voltage to the

motors, have been designed and put into service. These replace the usual resistor control, and provide for regenerative braking.

Possible Future Lines of Development

With regard to the future, it is hardly practicable to do more here than consider possible lines of development. Other more radical advances are, no doubt, conceivable, but in the absence of any positive indications of their practicability and value, the present review must be confined to those suggested technical advances on which a considered judgment can be formed.

Higher d.c. voltages than those in general use at present have been considered. Up to 6000V, the overhead line would present no new problem, as voltages as high as 20kV are already in use for single-phase alternating current, and there would be no fundamental difficulty in designing suitable mercury-arc rectifiers. Difficulties would, however, arise in designing track-feeder circuit breakers for d.c. voltages higher than those at present employed. With increased line voltage the disturbance in parallel communication circuits due to faults in the power circuit would tend to be greater, if advantage were taken of the higher voltage to increase the spacing between substations.

The design of the electrical equipment for locomotives and motor coaches becomes more difficult and expensive as the line voltage is raised, while the maintenance costs are also increased. If the present basic design of traction motor is adhered to, the maximum voltage per motor is about 1500V. For a line voltage above 3000V it would therefore be necessary to connect three or four motors permanently in series, and provide two such sets, comprising six or eight motors, for the complete equipment of a locomotive or motor coach. This is technically possible for locomotives without going beyond commonly accepted practice in locomotive design. For multiple-unit trains it would involve the use of three-axle bogies, equipped with six motors, or, if the line voltage were 6000V, two motor coaches each equipped with four motors, the two coaches being permanently coupled and operated as a single unit. Alternatively, the usual resistor control system could be replaced by a motor generator taking power from the line at, say, 4500V or 6000V and delivering power to the motors at a variable voltage with a maximum to suit the motor design. Such motor generators, however, would be costly, bulky and heavy.

Special designs could probably be developed with 2500V or 3000V per commutator, which would make possible the use of a line voltage up to 6000 with a four-motor equipment. They would be considerably larger than the motors of conventional design at present in use, and more expensive for equal horsepower capacity. It is also doubtful whether such motors could be made small enough for mounting on the bogie of a motor coach without unduly raising the height of the coach floor.

Difficulty would be experienced with the design of satisfactory auxiliary machines for voltages above 3000, and of circuit breakers for dealing with fault currents. The control equipment as a whole would probably have to be housed in the body of a motor coach on account of the increased size of the auxiliary machines, resistances and contactors.

In view of the difficulties and disadvantages of such an extra-high-voltage system, and of the probability that electrification on British Railways is likely to include provision for multiple-unit trains as well as for locomotives of different capacities, some large and others small, it is considered unnecessary, in deciding on the system for future electrification, to take account of the possibility of utilising direct current at any voltage above 3000V.

It has been suggested that some form of electronic control of d.c. traction equipments, other than grid-controlled mercury-arc rectifiers, might be developed to replace the present methods of control by resistors or variable-voltage motor generators. While such developments may well be possible, there has been so far, no indication of the method or apparatus likely to be used for this purpose. In any event, it could at the best only be regarded as a possible improvement in equipment design, and not as a development affecting the choice of system.

Completion of United Kingdom National Airways System

On completion of the final phase of the United Kingdom National Airways System, which is to come into operation next month, the whole network of Airways, which was begun on August 1, 1950, with the opening of Airway Green One from the Irish Sea to London, will be established.

The National Airways are, in effect, corridors 10 miles wide within which civil aircraft flying in bad weather at heights between 3000ft and 11,000ft are under the control of the ground organisation. The Airways are divided into sections by radio markers on the ground. The movement of aircraft in an Airway is so regulated by air traffic control that no two aircraft can be in the same place at the same height and time.

Phase II, which was introduced on February 15, 1951, extended Green One eastwards and brought into use Amber One (Daventry–Dunsfold–Dieppe–Paris), Amber Two (Paris–Abbeville – Maidstone – Brookmans Park – Daventry), Red One (Dunsfold–Maidstone–North Foreland–thence towards Amsterdam), and two connecting Airways crossing the London Control Zone and Control Area.

Phase III will extend Airway Amber One northwards to Prestwick via Burtonwood and the North-West Coast of England, and five new Airways will be brought into use. They are Green Two (Dublin–Liverpool/Manchester–Ottringham–N.W. Europe), Red Three (Belfast–Isle of Man–Liverpool/Manchester–London via Amber One), Blue Two (Belfast–Kintyre–Renfrew–Falkirk), and two short interconnecting airways serving Prestwick and Renfrew Airports.

With the introduction of Phase III, the Liverpool and Manchester Control Zones will be merged into one, and the Prestwick and Renfrew Control Zones will be replaced by a single "Scottish Control Zone." The first stage, on April 12th, will be the establishment of the Manchester Control Zone, the extension northwards of Airway Amber One as far as the Solway Firth, and the opening of Airways Green Two and Red Three. The final stage will follow early in May.

Pilots are in direct touch with the control staff by v.h.f. radio-telephone, based on a multi-carrier system.

UNITED KINGDOM NATIONAL AIRWAYS SYSTEM

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 24, Victoria Street, London, S.W.1.

INSULATING OIL (LOW VISCOSITY) FOR TRANSFORMERS AND SWITCHGEAR

No. 148 : 1951. This is a revised edition of B.S. 148, "Insulating Oils for Electrical Purposes (Excluding Cables)." The original edition was published in 1933 and dealt with six classes of oil, viz., A.0, A.10, A.30, B.0, B.10 and B.30, differing in allowable sludge limits and cold test temperatures. Experience has shown that while satisfactory performance in respect of freedom from sludge formation is provided in practice by oils meeting the sludge test limit for Class B oils, it is desirable to exclude oils of this class having a tendency to excessive formation of acidity. Such oils are accordingly excluded from this revision. Further, it is now considered unnecessary to provide a selection of oils having different temperature characteristics, and a maximum pour point of −25 deg. Fah. (−31·7 deg. Cent.) has been standardised as suitable for the majority of conditions. The revised edition of B.S. 148 is based largely on information supplied by the British Electrical and Allied Industries Research Association. Price 6s. post free.

THE ENGINEER

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PRELUDE TO THE BUDGET

ABOUT twelve months ago we remarked of the Economic Survey for 1950 that it was a somewhat dull document. But whatever other faults this year's Survey, issued last Tuesday, may possess, it certainly is not dull. The Survey for 1950 proved uninteresting because, though indeed it had to refer to the devaluation of sterling in the previous September, it could record thereafter only the steady progress made and the likelihood, just as apparent to all other observers as to its compilers, that similar progress would continue. It did not predict nor could it have been expected to predict the really startling change for the better in our external economic situation that took place during 1950. By contrast the Survey just issued relates to a year in which economic events are quite unpredictable with any pretension to certainty. In consequence, its assumptions, calculations and speculations attain a special interest as representing at least what the Government's advisors are thinking in confusing circumstances.

Two factors have combined to make any prophecies about the economic events of the remaining months of 1951 unusually hazardous. The first, of course, is the decision of this country, in company with other Western nations, to spend a larger fraction of its national income upon re-armament. That expenditure is to rise from £830 million in the financial year just ended to £1300 million in 1951–52 and to more than £1600 million in 1952–53. The other factor, one that stems from that same decision of the Western nations to re-arm, is the sharp increase in the demand for raw materials of several kinds, and the shortage of supply that has developed as the consequence of the inability of producing countries so suddenly to increase their outputs of them. Had those two factors not been present to complicate the issue, the 1951 Survey would, certainly, have predicted an increase in the industrial output of this country of some 7 per cent above that ruling in 1950. For, though in previous Surveys it has repeatedly been assumed that so high a rate of increase could not be any longer maintained (on the ground that it was connected with the re-conversion of factories from war to peace production), it has since been appreciated that it stems in reality from rapid improvements in productive methods and that under normal conditions it could therefore be expected to continue. But unfortunately, under present circumstances, even were it possible to assume that productivity would continue to improve at the same rate, it would still be too sanguine to suppose that the re-armament programme could be carried through with little or no reduction in the rates of supply of goods to the home and export markets and a mere check to their increase. Unhappily, however, it is not reasonable to make that assumption. For factories and shops cannot be re-equipped and re-tooled for armament production, nor can men be trained in their use and work up to a high rate of production without interruptions of output amounting perhaps to as much as the equivalent of three months' production by every shop concerned. Nor, unless the consultations now in progress amongst the Western Powers are successful beyond belief, is there much hope that shortage of raw materials will not imperil production schedules. The compilers of the Survey have therefore wisely assumed that so large an increase of productivity as 7 per cent cannot reasonably be predicted. Their estimate—it had better, perhaps, be termed a guess—is that it will amount to only 4 per cent, a prediction tantamount to saying that the rate of output ruling at the end of 1950 will be just about maintained throughout the whole of 1951, but not improved upon. Upon this estimate, one that pessimists will regard as unduly sanguine under the ruling uncertainties about raw material supply and about the availability for import of machine tools and other manufactured products needed for armament production, the financial calculations about this country's balance of payments and about its national expenditure and income are based. Much now depends upon how true the estimate will prove to be. For if, as optimists will hope, it turns out to be too low, standards of living in this country will be lowered less than is expected; and if it is too high, consumers here must experience a more serious depletion of goods to buy and, short of heroic measures to restrain wage increases or to increase savings, it is difficult to see how the inflation expected by the pessimists is to be avoided.

On another page of this issue we summarise those parts of the Survey more particularly likely to interest engineers. There is, then, no need to refer in detail to the figures here, further than to remark that, as in former Surveys, the compilers seem unduly optimistic about the output of the coal mines. Coal output in 1950 was 216 million tons, of which 12 million tons came from opencast workings. It is true that just latterly output has shown some improvement upon the figures for 1950. But is it really reasonable upon that ground to forecast an increase of production in 1951 to 219–222 million tons (11–12 million opencast)? As consistently as they have overestimated coal output, the Surveys have underestimated the output of the steel industry. It does seem, indeed, a fair assessment of the effects of raw material shortage that, despite increased capacity, the industry is unlikely to be able to improve upon last year's figures. Yet since the war the industry has so often triumphed over difficulties that it is tempting to hope that it will once more prove its ability to do so. But the main point to which reference is repeatedly made in the Survey is that shortages of raw materials are likely to persist. Undoubtedly in this present year it will be the supply of those materials that will mainly rule output. Yet it will not be wholly so. It is remarkable how, given the will and the incentive, men, and more particularly engineers, can and do triumph over difficulties. The shortage of some material may well act as a spur to the vigorous to apply ingenuity in discovering substitutes, in finding ways of economising in its use or in redesigning a product to achieve the same purpose at a more modest cost than the use of the scarce material would entail. In short, the scarcity of certain materials constitutes a challenge to the wits of engineers. They may yet prove in 1951 that, despite the raw material shortages, productivity can still be pressed upwards at as great a rate as ever!

THE UNIMPORTANCE OF AN AVERAGE

How convenient it is to strike an average! By the use of a single simple "mean" figure we seem to be able to summarise succinctly a great diversity of figures, to bring within our cognisance a whole wealth of detailed knowledge that it would take us endless time in any other way to memorise and appreciate. It is true that mathematicians give us an embarrassing choice between several kinds of "means" as arithmetic, geometric, &c., and we need to exercise discretion which we choose if we are to avoid their ire. Yet, given that care, the greater the number of figures we wish to summarise in an average or mean value the more accurate the value will be. The greater the apparent complexity, in fact, the more truthful, as well as the more helpful, the average seems to be. Further calculation is

immensely simplified, and the greater the number of units with which we have now to deal the more nearly will calculation from the average reflect the true result. By how much, then, has the concept of the mean value benefited the work of calculators! The average seems, indeed, at first sight, to be a Dr. Jekyll beneficently simplifying life and calculations. But, unfortunately, a little further experience proves it can also be a very Hyde. For what crimes of distortion of view have been committed in the name of the "average man"—that fellow who lives perpetually in the street! What perversities have been perpetuated by appealing to an average where an average cannot be soundly calculated or applied! What mistakes have been made by taking the average of averages! And especially what injustices have troubled mankind when the attempt has been made cold-bloodedly to apply so soul-destroying a concept, one fit only for mathematicians and statisticians to play with, to human beings!

Recently we read an article—it was one of many that have been written on similar subjects—in which the author reviewed the work of those who have been studying the influence of working hours upon the health and output of factory workers. He drew the conclusion that over a range of industry (in an "average" works, in fact!) the optimum output that could be reached by a male working force would be achieved in a fifty-six-hour week; but that the excess over the output in a forty-eight-hour week was so small as to make the longer working week hardly worth while. He demonstrated also that output quickly fell away when a working week of fifty-six hours was exceeded. It was, in fact, an admirable survey which showed very clearly what two World Wars have already taught in practice, that overlong working hours serve not to increase, but to reduce, total output. But to what extent can those conclusions be safely applied? For what is this optimum figure of fifty-six hours but that of the longest working week the "average" man can stand? Certainly it would be untrue to assume from it that all men can work fifty-six hours per week without ill-effects, and that none could work longer. The real meaning is that a proportion of men could work longer hours and still retain health, while a balancing number, even at fifty-six hours, are overworked by differing degrees to the extent that their outputs are individually less than the maxima of which they are capable. By applying this "average" fifty-six-hour week to all, on the unreal assumption that all have an ability equal to the average, an inhumanity would be created since the health of a proportion of the working force must then suffer. Working hours should, in fact, be equated not to those of which a non-existent "average man" is capable, but to those substantially lesser hours of which he who is most susceptible to overwork (though by no means necessarily the least valuable workman) is capable. Moreover, the real optimum output—an optimum higher than the maximum achieved by a uniform fifty-six-hour week—would be obtained not by getting all to work fifty-six hours each week but by letting each operator work the maximum number of hours (some less than fifty-six, some more) of which he individually was capable without injury to health—no doubt an impracticable suggestion.

But is there not some other error in all such calculations? For what do we mean by work? Men sleep for about eight hours each day. But they are awake and active for the remaining sixteen. Does a man's brain stop thinking, do his muscles cease acting when he is not officially at work? The young man whose health, it has unequivocally been proved, suffers if he "works" longer hours than about eight each weekday is not, in fact, so fatigued by his "work" that he cannot pursue an energetic sport in the evenings and at week-ends, nor is the executive after labouring mentally all day so worn out that he cannot play chess or bridge or read a learned book or indulge in quick-witted conversation afterwards. Why, then, is there so low a limit to working hours when men leaving work are daily ready to keep minds and bodies active upon something else? What is the difference between work and this recreation that fits us to work again? Why are we incapable of working all our waking hours? It is, perhaps, significant that we tire more easily when we lack interest in our employment than when we find it absorbing. If so, is it not possible that what we really need for continued health is not short working hours as such, but constant change of employment? Is not fatigue, in fact, a sign not so much of muscular or intellectual weariness as of approaching boredom? If so it seems probable, that unskilled men performing repetitive operations will tire far more easily than do skilled men able to some extent to choose each day between a variety of interesting tasks. That, if it could be proved a fact, would not be without significance in an age of production by repetitive operations. For it suggests that if health and output are to be maintained in a mass production factory hours of work will need to be substantially less there than those ruling in a general engineering works. It also suggests that "average" optimum hours calculated from a range of industry might well prove to be inhumanly long in such factories. For in any consideration of working hours we cannot safely calculate in terms of what an "average man" can do. Indeed when we apply an average to individuals, we are just as likely to be behaving like the inhuman Mr. Hyde as like the beneficent Dr. Jekyll.

The Economic Survey for 1951

THE Government's Economic Survey for 1951 was published as a White Paper (Cmd. 8195) on Tuesday afternoon. It is the fifth annual survey of its kind, and, as was to be expected, the hopes expressed in it and the forecasts made are tentative and conditional, in view of the economic implications of the rearmament programme, which, it has been estimated, will cost the country £4,700,000,000 over the next three years.

The survey stresses the seriousness of raw material shortages and though the hope is expressed that the discussions in Washington will lead to an easing of some of the most critical of those shortages, the Government recognises that scarcity of materials for civilian use must be faced in the interests of Allied defence production. It is not possible to count either on the necessary supplies being available or on the rise in import prices being kept within the limits assumed. From there, the survey goes on to say that very little contribution to increased production can be expected this year from an increase in employment and that output will depend almost entirely on the trend of productivity. Over the last three years productivity has risen by an average of 7 per cent a year and if there were adequate supplies of materials, it could be expected to go on rising at a similar rate. But, in the prevailing circumstances, it is assumed in the survey that industrial production this year will be about 4 per cent greater than in 1950.

Dealing with fuel and power, the survey notes the reversal of the downward trend in mining manpower and points out that 1,500,000 tons more coal were produced in the first ten weeks of this year than in the corresponding period of 1950. Subject to the many uncertainties in the situation, it continues, a total production of 219,000,000 to 222,000,000 tons of coal is looked for this year, made up of 208,000,000 to 210,000,000 tons from the deep mines and of 11,000,000 to 12,000,000 tons from opencast workings. The net increase in electricity generating capacity last year was the largest on record and, for the first time, installation of new turbo-alternators exceeded 1000MW. New construction is proceeding well and a steady increase in commissioning is expected this year, but, the survey warns, peak demand in the winter is likely to remain in excess of maximum generating capacity for some years to come. About iron and steel, it is estimated that, with the increased capacity now becoming available, 16,750,000 tons of steel ingots could be produced this year if there were sufficient raw materials. But owing to shortages of imported scrap and rich iron ore, crude steel production this year cannot be expected to exceed 16,000,000 to 16,250,000 tons and, the survey suggests, even that may be an optimistic forecast. Steel imports may be lower than last year owing to increased demand abroad and, with a substantial increase in the quantity needed for rearmament, steel exports will have to be reduced below the high rate achieved in 1950.

The paragraphs in the survey which discuss the metal-using industries are of particular interest. This group of industries, of course, includes all kinds of engineering, shipbuilding, electrical goods manufacture, rail and road vehicles, aircraft, precision instruments, drop forgings and brassware. Production in 1950 was 10 per cent higher than in the preceding year but it cannot be expected to increase by anything like as much this year, when supplies of steel and non-ferrous metals are limited. One of the most difficult problems, the survey comments, is the supply of machine tools. The retooling of existing plant and the creation of new capacity, particularly for jet aero-engines and tanks, will involve expenditure of over £100,000,000 on machine tools during the next two years. British output of metal-working machine tools, in 1950, was valued at £40,000,000, of which about two-fifths was exported. Production will be expanded where practicable and supplies for home civilian use and export will be reduced to make way for defence orders. Orders for machine tools are being placed abroad, in Belgium, France, Germany, Italy, Sweden, Switzerland and the United States. The motor industry will be required to devote more capacity to making tank and aircraft components and non-fighting vehicles for the Services. A reduction in supplies of sheet steel, resulting mainly from a cut in U.S. exports, has checked the rapid increase in production. To maintain exports home supplies of civilian vehicles are being curtailed, the allocation of new cars to the home market having been reduced from 110,000 in 1950 to 80,000, and of commercial vehicles from 105,000 to 80,000. It is hoped, however, the survey adds, that the total volume of exports from the metal-using trades will be maintained at the 1950 level. Total supplies of plant, machinery and vehicles for home investment should be maintained this year at about the 1950 level.

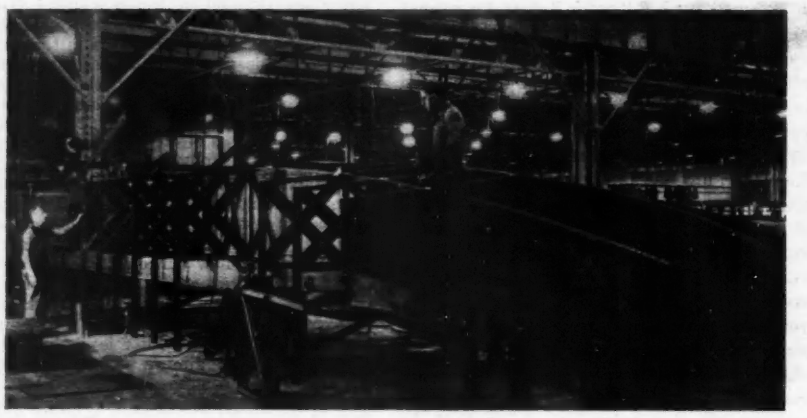
Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

AUSTRALIAN-BUILT LANDING CRAFT

SIR,—My attention has been drawn to an article in THE ENGINEER of December 8, 1950, entitled, "Naval Structural Trials."

During the war, the Royal Australian Engineers were responsible for the design, supervision of construction and manning of landing craft and small ships for the Army. Generally speaking, the Army west of Dutch New Guinea used American landing craft, &c., but east



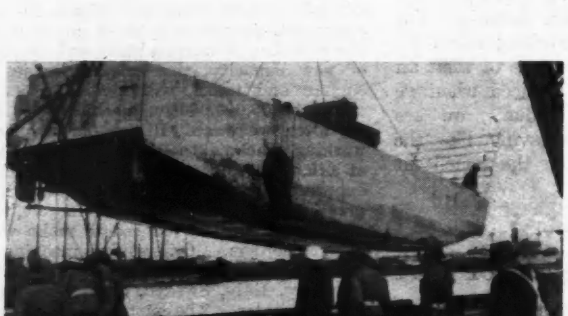
AUSTRALIAN LANDING CRAFT UNDER CONSTRUCTION

thereof the troops would have been immobilised without Australian craft, which were used almost exclusively. Sundry authorities at various times criticised them as being "all welded," "too rigid," "overstable," and "unseaworthy." Despite this, the R.A.E., from 1942–1945, had built, mainly by the Ford Motor Company of Australia, some five to six hundred landing craft and small ships.

The craft were designed as follows :—

(1) Being rectangular in section for more than half their length, they were treated generally as box girder sections, the deck and bottom being the flanges, the sides being the webs, all suitably braced and stiffened.

(2) All structural plating and members conformed to the S.A.A. code for structural steel in buildings, i.e., 8 tons per square inch maximum tension and $l/r = 120$ maximum for compression members, &c.



LANDING CRAFT LOADED WITH TANK

(3) The ship was designed :—

(*a*) To balance in air fully loaded, on a knife edge, or be similarly supported at any two points; or

(*b*) So that it was not overstressed if it was immersed empty into water of depth equal to the distance from maindeck to the bottom of the ship plus 50 per cent for impact, which ever was the greater.

(4) The ships were suitably knee-braced and decks designed for Army tanks.

I mention these factors, not because they appear to be novel but because of the wave of criticism which their practical application caused, as mentioned above. However, no craft foundered despite an occasional cyclone, and they stood up to punishment from the Japanese better than their contemporaries.

My conclusion from this, if I may have one, is that strong and "rigid" ships can be built with economy of materials, i.e., the ships do not have to be so substantially constructed that the weight or volume of the cargo is curtailed. By "rigid" is meant rigid within the elasticity allowed in a steel building frame.

C. S. STEELE

Melbourne, Australia, March 8th.

NOT A USUAL SORT OF JOB

SIR,—With reference to the letter under the heading "Not A Usual Sort of Job," in THE ENGINEER of March 23, 1951, may an engineer, who is married to a children's specialist, comment on the misleading nature of the letter.

(1) It is not stated what type of feeding-bottle is being used. There are two types in common use: the boat (which is not recommended), which has a valve in addition to a teat, and the soxhlet, which is fitted with a teat only. The type used will clearly affect the calibration.

(2) The position in which the child is to be fed will also greatly affect the suction exerted by it and the desirable rate of feed. It will be clear to engineers who have studied the simple mechanics of the body that the nearer the child can be to the vertical the better are the conditions both for taking in its feed and for bringing up its wind.

(3) No reference is made to the viscosity of the feed, which will, in general, increase with the age of the infant.

(4) No reference is made to the fact that the normal teat becomes softer with repeated sterilising and gives a very greatly increased rate of feed in the process.

(5) There is one positive misstatement to the effect that the length of feeding time should remain constant. In fact, for the average child the feeding time will probably halve in a six months' feeding period.

(6) The perfect test is, in fact, the simplest one. Whatever the type of bottle, when it is first held upside down, the liquid content should initially come in a free series of individual drops. Naturally, as a vacuum develops in the soxhlet type of bottle, it will stop dripping.

Since the medical profession is jealous of even indirect advertising by its members, may I sign myself,

D. B. W.

Cheshire, March 27th.

SOME AMERICAN LOCOMOTIVES AND THEIR RUNNING

SIR,—On page 225 of the issue of THE ENGINEER of September 1, 1950, it is mentioned in my article that the New York Central 4–8–4 locomotive is fitted with a H.T. stoker made by the Locomotive Equipment Company of Toledo, Ohio.

I have been requested by the Standard Stoker Company, Inc., Erie, Pennsylvania, to state that the stoker itself is manufactured by them and that the name of the Locomotive Equipment Company referred only to the fire-door, from which I read it.

W. A. TUPLIN

Huddersfield, March 28th.

EARLY MOTOR-CARS

SIR,—In THE ENGINEER of January 22, 1897, a letter was published signed "Outsider," giving information of great interest about motor-cars of that time.

Can any of your readers identify the writer of that letter?

JOHN SHEARMAN

Chichester, March 31st.

BOOKS RECEIVED

Examples in Practical Mathematics. By C. C. T. Baker. London: English Universities Press, Ltd., St. Paul's House, Warwick Square, E.C.4. Price 6s. 6d.

Resistance Welding, Designing, Tooling and Applications. By Wallace A. Stanley. New York: McGraw-Hill Book Company, Inc. Price 7.50 dollars.

Inelastic Behaviour of Engineering Materials and Structures. By A. M. Freudenthal. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 60s.

Warm Air Heating and Winter Air Conditioning. By John W. Norris. London: McGraw Hill Publishing Company, Ltd., Aldwych House, W.C.2. Price 55s. 6d.

The Nomogram. By H. J. Allcock and J. Reginald Jones. London: Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 18s.

Air Compressors: Control and Installation. By P. C. Bevis. London: Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 20s.

Mechanical Engineering Science. Vol. II. By J. D. Walker. London: English Universities Press, Ltd., St. Paul's House, Warwick Square, E.C.4. Price 10s. 6d.

Building Construction and Drawing. Twentieth edition. By George A. Mitchell and A. M. Mitchell. London: B. T. Batsford, Ltd., 15, North Audley Street, W.1. Price 10s. 6d.

Economic Design of Rectangular Reinforced Concrete Sections. By T. P. O'Sullivan. London: Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 12s. 6d.

Leipzig Technical Fair

No. II—*(Continued from page 408, March 30th)*

AMONG the machine tools seen at the Leipzig Technical Fair was a new internal grinding machine, exhibited by the WMW Schleifmaschinenbau, Berlin VEB, of Berlin, O.17. It takes work from 10mm to 125mm diameter, in lengths up to 175mm. Six workhead speeds, giving a range of 85 r.p.m. to 500 r.p.m., are provided, and for mass-production work electrically-operated diameter measuring equipment can be fitted. When the face-grinding head, to be seen at the top of our illustration, Fig. 7, is swung down, the grinding-wheel spindle starts, and it is stopped when the arm carrying the head is returned to its rest position. All facing operations, including conical work, can be carried out with this attachment. The same firm also exhibited a large centreless grinding machine for diameters up to 200mm. A similar exhibit for grinding stepped spindles has capacity for work of up to 128mm diameter.

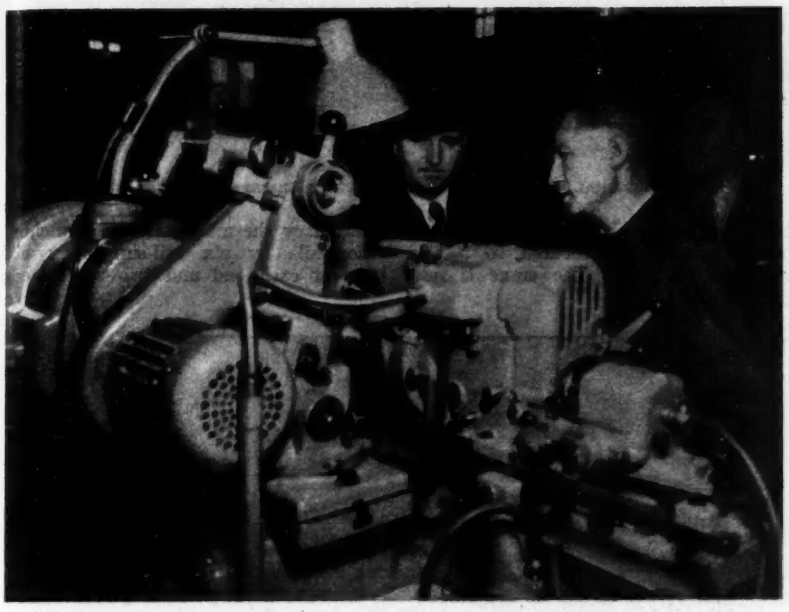


FIG. 7—INTERNAL GRINDING MACHINE—W.M.W.

For the first time this year examples of the production of the WMW Pittler Werkzeugmaschinenfabrik VEB Leipzig were on view. A new turret lathe exhibited embodies several new features. This machine is illustrated in our engraving, Fig. 8. The spindle head is bored to take up to 50mm diameter rod, and chuck work up to 160mm diameter can be accommodated or, when using a small number of tools, up to 225mm. The turret has twelve to sixteen tool sockets and with the low setting of the horizontal bearing of the turret, it is claimed that transverse movements of the tool can be achieved without the use of special slides. The large tool sockets of the machine, combined with its higher speeds and feeds, have greatly increased the capacity of the lathe. All controls are conveniently grouped at the front of the machine. Central lubrication is arranged for the working spindle, for the feed gears and the turret slides.

A large lathe, shown by the WMW Maschinenfabrik Meuselwitz VEB, was developed in collaboration with the Eastern Zone Government rolling mills, for the turning of rolls. It has a total weight of 25 tons and is driven by a 30kW slip-ring motor. The headstock and tailstock are fitted with chucks for roughing operations and for finish machining a rotating centre is fitted in the tailstock. Two sets of roll carriers are provided, so that when finish machining rolls, the diameters and forms of the mating rolls can be compared and checked.

A large number of milling machines shown by the WMW Wanderer Fräsmaschinenbau Chemnitz VEB, included new models of horizontal and vertical milling machines.

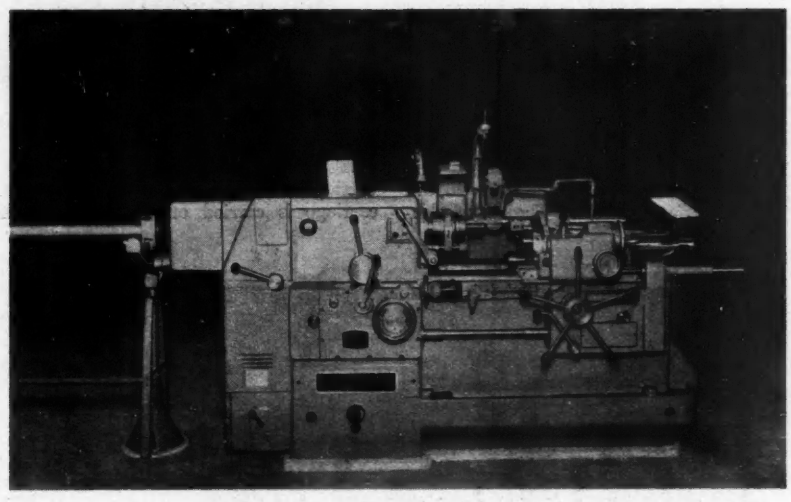


FIG. 8—PITTLER HIGH SPEED TURRET LATHE—W.M.W.

COLLECTIVE EXHIBITS

Again the biggest collective exhibit was that staged by the Soviet Union in Hall No. V. A large section was devoted to agricultural machinery and Russian agricultural methods. There was also a section of road-making and road-repairing equipment and some examples of motor-cars and road and rail transport vehicles.

The machine tools comprised a full range and among them we noted several large machines. Many of the machines were shown in operation and high outputs, using modern tools and special Russian free-cutting steels, were demonstrated. A group of large photographs showed the civil engineering work now going on in connection with the Kuibyschwew and Zymljanskaja power stations and canal building in the South Ukraine, the Crimea and on the Volga-Don scheme.

In the Czechoslovakian collection there was a good display of machine tools; an example of crankshaft work from the Wilkowitz Steelworks and a turbine rotor from the Skoda works. Machine tools were also shown in the Hungarian section and in the Polish exhibit, which was largely concerned with railway repair shop plant. In the Republic of China exhibit there was reference to Chinese produced steel and non-ferrous metals.

GENERAL MACHINERY EXHIBITS

In the woodworking machinery section was shown a representative exhibit, arranged by LBH Vereinigung Volkseigener Betriebe Land, Bau und Holzbearbeitungsmaschinen Leipzig. This group also staged a representative show of agricultural implements. Amongst these machines we noted a new saw frame, made by the Herkules Sägegatter Werk VEB, of Aue, Saxony, in which hydraulically controlled rollers for the feed were employed. This firm also exhibited a frame-saw mounted on a trailer wagon, on which it can be taken into the forest, and arranged to form a complete sawing plant.

In the prime mover section several diesel engines were exhibited. The Maschinenfabrik Buckau-Wolf, of Magdeburg, one of the group of the Soviet Maschinenbau A.G. AMO, showed a six-cylinder marine engine with an output of 400 h.p. to 540 h.p at 275 r.p.m. to 375 r.p.m., also an auxiliary engine with four cylinders, having an output of 80 h.p. to 100 h.p. at 600 r.p.m. to 750 r.p.m. Under the group known as the EKM Vereinigung Volkseigener Betriebe, des Energie und Kraftmaschinenbaus of

Halle (Saale), a large four-stroke eight-cylinder engine was exhibited with a designed output of 710 h.p. to 920 h.p. at speeds from 250 r.p.m. to 333 r.p.m. Four-cylinder auxiliary engines of the same design were on view, having an output of 210 h.p. to 250 h.p. at 375 r.p.m. to 500 r.p.m. The EKM Elbe-Werk of Rosslau, showed a new, small diesel engine with an output of 30 h.p. to 36 h.p. at 800 r.p.m. to 1000 r.p.m., for auxiliary and generator driving.

Among the compressors was a large town gas horizontal compressor, built by the EKM Zwickauer Maschinenfabrik of Saxony, to deal with 320 cubic metres of gas per hour compressed to 285 or 320 atmospheres. The compressor was driven by a 900 h.p. electric motor set between the two lines of compressor cylinders. Finally, the EKM Dampfkesselbau of Meerane, displayed on its stand an exhaust gas boiler with forced circulation, with an output of 6 tons of steam per hour at a pressure of 13 atmospheres and a superheated temperature of 350 deg. Cent. In this section the Krupp-Gruson Maschinenfabrik of Magdeburg showed hot presses for pneumatic tyres and various kinds of crushing plants.

In the section dealing with material testing the firm of Joh Alfred Richter, Refrigerating Plants Gm.b.H., of Berlin O.17, Warschauer Strasse 35–36, exhibited a large plant designed for testing materials, using alternating temperatures from +100 deg. to −100 deg. Cent. Our engravings, Fig. 9 and 10, show the general layout of the plant. The testing-room, which in the largest size of machine may measure 1000mm all ways, is lighted internally and is wired for full instrumentation. The arrangement of the switchboard with its recording instruments and refrigerating plant and vacuum pump, will be seen in the illustrations. The plant is designed for fully automatic operation over any desired temperature and pressure range.

Some Outside Exhibits

Prominent among the outside exhibits were the two general purpose railway cranes, built by the Kranbauwerk der A.G. Transmasch, formerly the firm of Unruh and Liebig of Leipzig. The largest of these was a 50-ton crane with a welded jib. It is diesel-electrically operated and has a total weight of some 98 tons. The unit is fully equipped for night work with searchlights and with acoustic and visual signalling. The second crane, illustrated herewith in Fig. 11, has a lifting capacity between 25 and 10 tons at different radii. The diesel-electric machinery, enclosed within the body of the crane, comprises a Buckau-Wolf four-cylinder engine, driving a 60kVA Finsterwalde alternator. The body is mounted on a turntable, which is secured to a base travelling on a rack. The crane is fully rotating and can travel on the undercarriage a distance of 9m. The undercarriage is carried on six pairs of wheels, two of which are driven from the crane diesel-electric generator set for travelling and manœuvring purposes. When stationary the undercarriage is anchored to the rails by six rail-supporting clamps, two at each end and two at the corners. These clamps are operated hydraulically by oil pressure.

Fig. 11—General Purpose 25-Ton Railway Crane—Unruh and Liebig

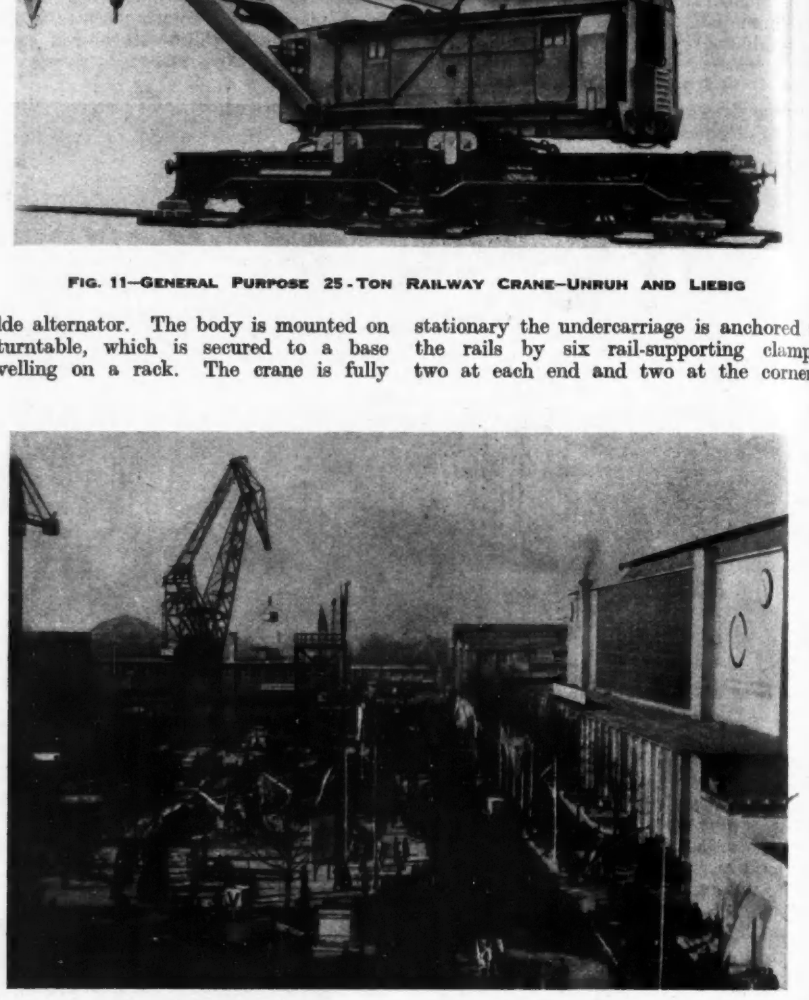
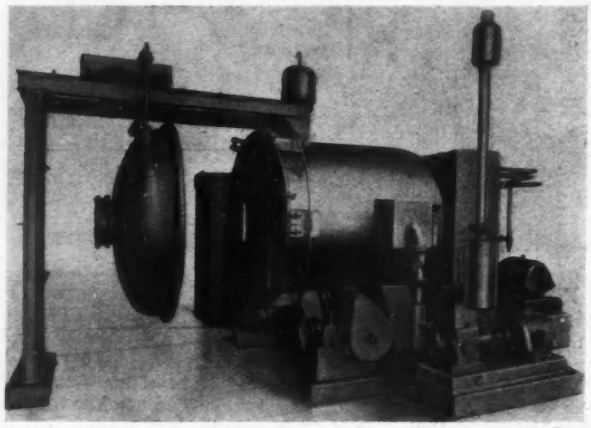


Fig. 12—Hall X and Abus Open Air Exhibits

Among other open-air exhibits were



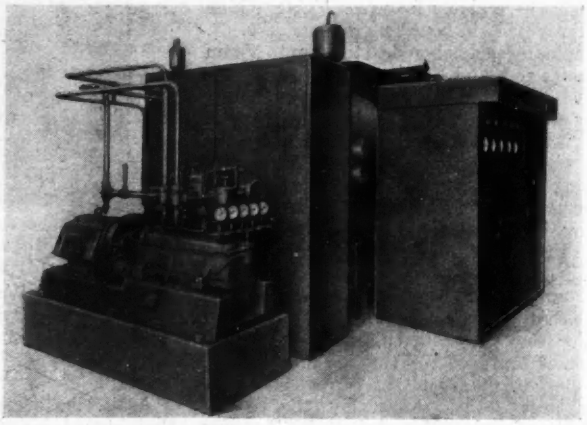


Fig. 9 & 10—Material Testing Plant—Richter

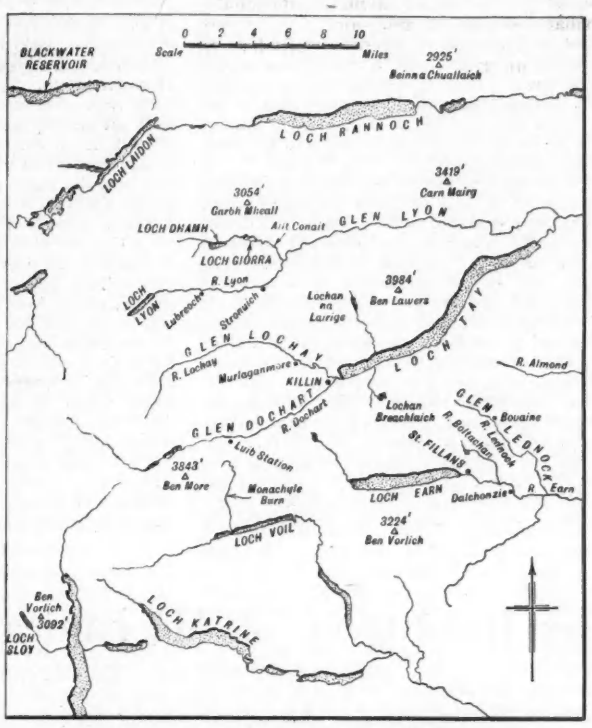
several battery-driven electric trucks by the Bleichert Transportanlagenfabrik of Transmasch A.G. Leipzig. The same firm showed a new slewing crane on a battery-driven electric truck with a lifting capacity of 5 tons, named the "Aktivist." Examples were also shown of the Bleichert ball-shovel digging material and delivering it into dumping wagons. This machine consists of a tubular member with a belt conveyor inside it. The head is of truncated conical shape and has a series of serrated cutting edges, which deliver the material on to the conveyor. From the tube conveyor the material falls into a conical chute, which delivers it to another belt conveyor, which can be swung about 72 deg. to either side and also raised nad lowered for loading material into trucks or wagons. The cutting head is driven through a crown wheel meshing with a pinion on a shaft mounted on the top of the tubular member. The cutting head can be swung sideways through 300 deg. and also raised and lowered vertically. The digger is mounted upon caterpillar tracks and it is electrically driven. Its capacity when freely digging sand or gravel is about 90 cubic metres per hour and about 35 cubic metres per hour when handling harder material.

In the general view of open-air exhibits, shown in Fig. 12, there will be seen two examples of the building and wharf cranes made by the ABUS or Vereinigung Volkseigener Betriebe für die Austrüstung von Bergbau und Schwerindustrie of Halle (Saale). The crane for port and harbour work exhibited is one of a series supplied to ports in the Eastern Zone. It has a special jib, which for luffing purposes is supported at a point about two-thirds of its length and is controlled from the end by a counterbalance. The crane can be swung in a circle and it is pointed out by the makers that the design adopted enables two cranes to work a single hold when loading or unloading ships. These cranes are built for loads of 30, 25 and 20 tons with jib radii of 10m, 22m, 26m and 33m.

Some Railway Exhibits

Brief mention may be made of some of the railway exhibits shown in the accompanying engraving, Fig. 13. The LOWA Vereinigung Volkseigener Betriebe Locomotiv und Waggonbau, of Wildau, Kreis Teltow, showed from its many works a wide range of railway plant. Of special interest was the powdered coal locomotive, built by the LOWA Karl Marx Werk of Babelsberg. It will be seen to the right of our engraving. It is a superheated three-cylinder compound, express goods locomotive and has a forced circulation La Mont boiler, fired with powdered coal. The tender is arranged as a condenser. The locomotive is of 2900 h.p. and has a boiler working pressure of 42 atmospheres. It is stated to have a maximum speed of 100km per hour. The engine and tender weigh 200 metric tons in working order.

The VEB Waggonbau Görlitz and Bautzen showed examples of modern corridor rolling stock. Other exhibits included shunting locomotives, a fireless locomotive, examples of tramway car construction, refrigerated wagons and examples of reconstructed rolling stock.



CATCHMENTS OF THE BREADALBANE DEVELOPMENT

The Breadalbane and Kilmelfort Hydro-Electric Schemes

The North of Scotland Hydro-Electric Board has given details of its Breadalbane scheme (Constructional Scheme No. 25), which, it is estimated, will have an average annual output of 304 million units of electricity by using the water power resources of 186 square miles of Perthshire. The Breadalbane scheme is in three sections (Killin, Luib and St. Fillans), and it is estimated that it will cost over £15 million. It provides for the use of the head waters and tributaries of the Rivers Lyon, Lochay, Dochart, Lednock and Almond, the Monachyle Burn and Loch Earn, which are shown in the accompanying map.

The area to be developed is bounded on the north by the catchment of the Tummel Garry project (Loch Rannoch) and the Lochaber hydro-electric development lies to the north-west (Blackwater reservoir). To the south-west lies Loch Lomond, with the catchment of the Loch Sloy project on its western side and the Glasgow Corporation Water Department's source of supply at Loch Katrine on its eastern side. The Board's Constructional Scheme No. 18, the Lawers project, which has already been approved by Parliament, and which will consist of a reservoir at Lochan na Lairige and a 30MW generating station beside Loch Tay, with an output from 71 to 80 million kWh annually, will be linked to and controlled with the power stations of the Breadalbane scheme from a control centre at Killin. The eight stations of the group will have a total capacity of 118·5MW and an average estimated annual output of 384 million kWh. It is expected that work will soon be started on the Lawers scheme.

The works to be constructed in the Killin section of the Breadalbane scheme itself include three dams and three generating stations. Two of the dams are to be in Glen Lyon. The main one will be across the River Lyon near Lubreoch and will enlarge Loch Lyon. Additional water will be brought by aqueduct from Glen Lochay into this reservoir. Lubreoch generating station will be built into this dam, and will discharge water down the River Lyon to a second dam near Stronuich. This dam will form a much smaller reservoir on the north shore of which will be the Giorra generating station, while on the south shore will be the intake of a tunnel leading to Glen Lochay. Further substantial storage will be obtained by the construction of a dam across the Allt Conait to enlarge and unite Lochs Dhamh and Giorra. The water from this reservoir will be led through a tunnel to the Giorra power station, and will then be discharged into the reservoir at Stronuich.

The water from the small reservoir at Stronuich will pass through the tunnel to the Lochay power station in Glen Lochay near Murlaganmore. This station, which will have a capacity of 45/50MW, will discharge into the

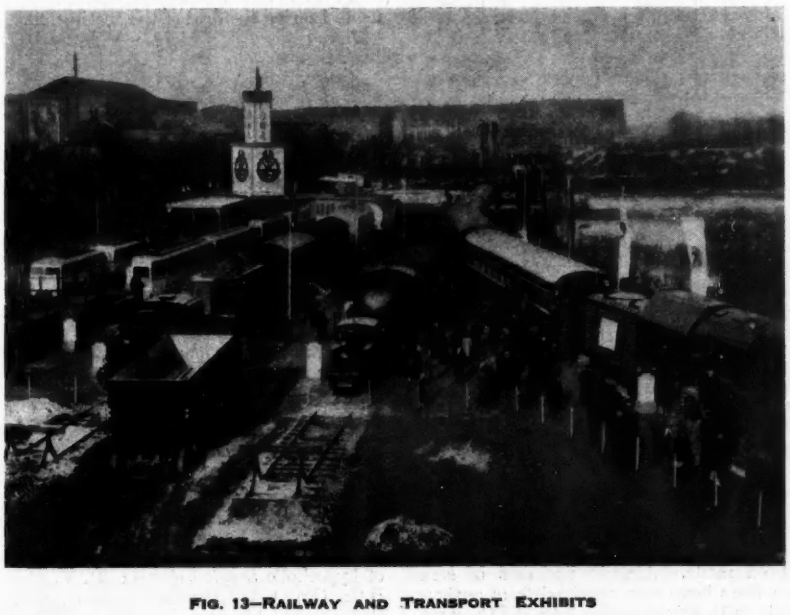


FIG. 13—RAILWAY AND TRANSPORT EXHIBITS

River Lochay. Additional water from certain of the head streams of the Rivers Dochart and Lochay will be collected by aqueduct and diverted into the pipe-line which supplies the Lochay generating station.

The Luib section of the scheme consists of collecting aqueducts and a small dam across the Monachyle Burn in the hills to the south of Luib. From this small loch, water will be led by tunnel and pipe-line to a generating station 965ft below on the River Dochart to the west of Luib railway station.

The St. Fillans section will involve the construction of a dam at the outlet of Lochan Breachlaich, and the water so impounded will be taken by tunnel to the Lednock generating station in Glen Lednock. This generating station will be on the shores of a reservoir to be formed by a dam across the River Lednock near Bovaine. From this reservoir, into which additional water from the Almond, Boltachan and other streams will be diverted by aqueducts, a tunnel and pipe-line will supply the St. Fillans generating station 830ft below on the shores of Loch Earn. The St. Fillans generating station will have a capacity of 22MW. The scheme will also make use of the natural flow from Loch Earn. A tunnel will be driven from a point near the outlet of the loch to the Comrie generating station, which will be situated on the south bank of the River Earn further downstream near Dalchonzie.

The Kilmelfort Scheme

The Kilmelfort Scheme (Constructional Scheme No. 61), is a small scheme with an estimated annual production of 9,000,000 units in Western Argyll. The scheme will utilise a catchment area of 11 square miles of the River Oude, with an annual rainfall of approximately 74in.

Loch na Sreinge will be impounded by a small dam at its northern end. An aqueduct will lead the water from the loch into a stream which feeds into Lochan a'Bhailis and Loch Tralaig. Loch Tralaig itself will be impounded by a dam on the River Oude, near the outlet of the loch, to provide the main storage reservoir of the scheme with a capacity of 133 million cubic feet. Water from Loch Tralaig will be released down the River Oude to a small headpond to be formed in the Pass of Melfort by a dam across the River Oude. The Eas Tarsiunn burn will be tapped and some of its water taken by aqueduct to this headpond. From the headpond the water will be led by tunnel and pipe-line to a generating station on the left-hand bank of the River Oude, near its outlet into Loch Melfort. The generating station will contain one 3MW turbo-alternator operating under a gross head of 365ft.

The Institution of Mechanical Engineers

ANNUAL REPORT OF THE COUNCIL

LAST Friday, at a General Meeting, the Council of the Institution of Mechanical Engineers presented its annual report for 1950. We reproduce some extracts from it on the work and progress of the Institution during 1950.

Membership

The Numbers on the Register During 1950 are Shown in the Following Tabulated Statement

	Hon. M.	M.	A.M.	C.	Assoc.	G.	S.	Totals	
Totals at December 31, 1949	27	4,661	13,704	32	979	9,232	4,684		33,319
Elected	2	41	298	1	43	1,335	919		
Reinstated	—	1	2	—	1	1	2		
Transferred	—	134	643	2	10	752	—		
Total additions during 1950	2	176	943	3	54	2,088	921	+4,187	
Deceased	1	105	98	1	4	5	8		
Resigned	—	13	46	—	15	57	118		
Erased	—	16	46	—	10	44	71		
Elections voided	—	—	—	—	4	2	31		
Transferred	—	—	133	—	24	625	759		
Lapsed	—	—	—	—	—	36	139		
Total deductions during 1950	1	134	323	1	57	769	1,126	−2,411	
Net alterations during 1950	+1	+42	+620	+2	−3	+1,319	−205		+1,776
Totals at December 31, 1950	28	4,703	14,324	34	976	10,551	4,479		35,095

The Summer Meeting was held in Birmingham on Wednesday, Thursday and Friday, June 21st, 22nd and 23rd, and 511 members, accompanied by 253 ladies, registered for the meeting. A wide variety of engineering works and other places of interest in Birmingham and district were visited during the meeting, and the hospitality of the many hosts was greatly appreciated by all those who took part. The Council wishes to record its thanks to the numerous generous hosts and to the officers and members of the reception committees whose efforts contributed so largely to the success and enjoyment of the meeting.

Conference of Engineering Institutions of the British Commonwealth

At the invitation of the South African Engineering Institutions, the second meeting of the Conference of Engineering Institutions of the British Commonwealth was held in Johannesburg from April 11 to 20, 1950. Our own Institution was represented by the President, Dr. S. F. Dorey, C.B.E., M.I.Mech.E., F.R.S., and the Secretary, Sir Henry Guy, C.B.E., D.Sc., M.I.Mech.E., F.R.S. The Institution of Civil Engineers and the Institution of Electrical Engineers were represented by their respective Presidents and Secretaries and there were representatives of certain engineering institutions of Australia, Canada, New Zealand and South Africa. The Conference held nine sessions and the results of its labours, expressed in the form of recommendations and resolutions, have since been adopted and endorsed by the Councils of the Institutions represented, save that the New Zealand Institution of Engineers preferred neither to confirm nor to reject one recommendation. Since the Conference, the Institution of Engineers (India) has adopted and endorsed, with two exceptions, all the recommendations and resolutions of the Conference. A full account of the work of the Conference was published in the December *Journal* (1950, pages 206–209).

General Discussion on Heat Transfer, 1951

Arrangements for the proposed General Discussion have been placed in the hands of an executive committee and good progress has been made. Already promises of some forty papers have been received from authors, not only in Britain, but also from the Commonwealth and Europe. About the same number of papers has been promised to the American Society of Mechanical Engineers, which is co-operating with the Institution in this activity. The Conference has the support of the leading technical societies at home and abroad. The subject-matter of the discussion has been divided into the following five main headings: Heat Transfer with Change of State; Heat Transfer between Fluids and Surfaces; Conduction in Solids and Fluids; Radiation, Instrumentation, Measurement Techniques and Analogies, and Special Problems. The dates for the General Discussion will be Tuesday, September 11, to Thursday, September 13, 1951, inclusive.

Specialist Groups

The Specialist Groups had a successful year of meetings and the discussions on the numerous papers presented were sustained and lively. It is of interest to note that one group, Industrial Administration and Engineering Production, had as many as five meetings; the Applied Mechanics Group had three, Hydraulics three, Steam two, and the Education Group one meeting. It was not found possible during the year to recommence the remaining Group, namely that on Internal Combustion Engines.

James Clayton Fund

The bequest under the will of the late Mr. James Clayton provides for the annual award of a prize, a lecture or lectures, and of fellowships bearing his name. The following particulars relate to the administration of the fund during the year.

Award of the 1949 *James Clayton Prize.*—The will provides that a sum not less than one-quarter of the annual income shall be awarded as a prize to a Member, Associate Member, Graduate, or Student, who, in the opinion of the Council, has contributed most in the year to modern mechanical engineering science by way of research, invention, or experimental work; or by a treatise or paper on a modern mechanical engineering subject; or by originality in design; or by service to mechanical engineering.

The Council considered that the most outstanding contributions to mechanical engineering science within the terms of the trust were those of Mr. C. C. Pounder, M.I.Mech.E., to the advancement of mechanical engineering science by way of invention, design and investigation, communicated in part in his paper on "Some Current Types of Marine Diesel Engines" to the Institution in March, 1949. The Council accordingly decided that the amount available for the prize, £1450, be awarded to him. The prize was presented to Mr. Pounder at the General Meeting on February 17th and was accompanied by a certificate bearing the Seal of the Institution.

James Clayton Lecture.—A James Clayton Lecture was delivered by Mr. C. G. A. Rosen.

Awards under the James Clayton and Manville Bequest Funds.—In June six Fellowships and three grants were made from the James Clayton Bequest Fund, amounting in all to more than £3000. One Fellowship was awarded from the Manville Bequest Fund and the recipient was awarded a supplementary grant from the Clayton Bequest. This grant is one of the three grants just mentioned. The names of the recipients and their schemes of work are set out below.

Clayton Fellowships.—Frank Ellis, B.Sc. (Eng.), G.I.Mech.E., Theoretical and experimental research at the Imperial College on hot and cold rolling. This is an extension of a 1949 fellowship; J. Halling, B.Sc. (Eng.), G.I.Mech.E., research at City and Guilds Engineering College, London, on rolling friction with special reference to surface finish; E. P. Hotchen, B.Sc., G.I.Mech.E., research at Manchester College of Technology on flue-gas temperatures; John Houghton, B.Sc. (Eng.), G.I.Mech.E., research at Queen Mary College, London, on the effect of end-constraint on thin-walled and solid cylinders of hyperbolic aerofoil shape; R. V. Macbeth, B.Sc. (Eng.), G.I.Mech.E., research at King's College, London, on the combustion of oil fuels; Gerald Moss, B.Sc. (Eng.), G.I.Mech.E., an investigation at King's College, London, of a new form of continuous filter.

Clayton Grants.—H. C. Barty, A.M.I.Mech.E.,

investigations of a hydraulic damper to restrain unwanted motions of chassis frames; Eric Harvey, B.Sc. (Eng.), G.I.Mech.E., research on a method of jet propulsion for marine application.

Manville Fellowship and Clayton Grant.—Brian Mills, B.Sc. (Eng.), G.I.Mech.E., research at Birmingham University on flow characteristics of poppet-type exhaust valves. This is an extension of a Manville Fellowship (1949) and Clayton Grant (1949).

Researches in Progress or Completed During the Year: Cambridge University.—Experiments were carried out in flight on the possibility of obtaining laminar instead of turbulent boundary layer flow on aircraft by making the surfaces porous and applying suction from within. Laboratory tests were also made in thin boundary layers with specially designed, very small Pitot tubes. The research into the stresses in gear teeth in motion, by photo-elastic methods, has been temporarily suspended.

Birmingham University.—Experiments on the flow characteristics of poppet valves have shown a serious discontinuity in the flow behaviour due to certain humidity effects. This phase has been investigated and now it is complete the main programme of observations on a simplified system equivalent to the poppet valve is being resumed.

Manchester College of Technology.—A theoretical and experimental investigation has been completed on fatigue properties of metals and particularly of stress distribution in a semi-circular notch on cylindrical specimens subjected to fatigue loading for alternating and pulsating loads. For some of the specimens the tests have been taken well into the plastic range.

Imperial College.—Progress is being made on a problem of three-dimensional photo-elasticity by using the method known as "stress freezing" followed by the cutting of slices in appropriate planes. A special heating oven and an experimental rolling mill have been designed for determining stresses by this method in rolled specimens.

The latent heats of mixtures of ethylene and carbon dioxide have been accurately determined at known temperatures and the results compared with the Clausius-Clapeyron equation. The researches throw some doubt on the accepted values for the latent heat of pure ethylene. For carbon dioxide there was agreement with accepted values. This stage of the research is completed.

Joint Overseas Groups

The Council is collaborating with the Councils of the Institution of Civil Engineers and the Institution of Electrical Engineers to provide facilities for members in certain territories overseas of the three Institutions to meet together for the purposes of holding meetings at which papers of mutual engineering interest are presented and discussed, to arrange visits to works, &c.

Abadan Joint Overseas Group.—The Group Committee has organised an attractive programme of meetings and visits since its formation in December, 1949, and an interesting programme of activities has been planned for the next session.

Argentine Joint Overseas Group.—During the year the Council agreed to implement the desire of the Committee of the River Plate Branch to participate in the formation of this Group, which will focus the activities of the Institution in that area and resulted in the closing of the Branch. The Group is now holding meetings and arranging visits.

Consideration is being given to the possible formation of other Joint Overseas Groups. It is not intended that Joint Overseas Groups shall be established in a Dominion where a "recognised" national engineering body exists, but they are intended to meet the needs of members resident in areas where there is no organisation already established or where sufficient membership of the three Institutions would justify their establishment.

Library and Reading Room

During the latter half of the year the front Library has undergone a partial reconstruction with alterations to existing bookcases and a gallery round the room has been added. In spite of this work a full service has been maintained. The alterations will provide additional accommodation, which has become necessary for the ever-growing stock of books. The work has been carried out by G. M. Hammer and Co., Ltd., of Harringay, to the plans of their designer, Mr. G. H. Chantrell. The lighting in the library has been extensively rearranged and members will find that the alterations as a whole give a dignified effect in what was already a fine room.

During the year 2637 publications were acquired, bringing the total stock to over 47,000. The number of loans, many of which were dealt with through the post, reached a record of 11,807.

Much use has also been made of the collection of 400 British and foreign technical periodical publications exhibited in the reading room. As this collection is constantly added to as new periodicals are published, members are able to keep abreast of the latest world developments in engineering and related subjects. Many of the periodicals are subsequently bound for permanent preservation in the library, where indexes to their contents, such as *The Engineering Index* and *The Industrial Arts Index*, are available for reference.

Inventions and Research

Pipe Flanges Research Committee.—In consequence of further calculations needed in the revision of B.S. Specification for Flanges for Steam Pipes at High Pressures, it has not yet been found possible to complete the Committee's Third Report.

King's College, London.—The small-scale differential analyser has been completed and assembled. The various units have been run for purposes of test and adjustment and only minor modifications to the original design have been found desirable. Various test equations have been solved and it is expected that the machine will be applied to the examination of specific engineering problems in the near future.

Leeds University.—The work on curvature corrections for helical torsion springs from round wire has been completed and further tests, extending to the range of wire sizes examined, have been undertaken. The work on shot peening has progressed to the stage where scatter band curves, for both the shot peened and not shot peened conditions, with a mean bending stress of 35 tons per square inch has been completed. Similar work at a mean stress of 40 tons per square inch is in hand and will be followed by work at 30 tons per square inch mean stress.

Manchester College of Technology.—The results of the research into taps and tapping have been recorded in the form of a paper presented at a general meeting of the Institution. Work is being continued on the fundamentals of the metal cutting process and it is expected that a report will be available shortly.

Royal Anthropological Institute.—Iron objects were examined from Persian Azarbaijan. This work is of particular value as the iron examined has been dated to the third or early second millennium B.C. A short report has been published on Pattern Welding of a Viking period iron spearhead. Metallographic examination has been carried out in pieces of strip copper from Egypt of the First Dynasty period with the object of determining the method employed to produce copper strip of extreme thickness.

Benevolent Fund

The Council draws attention to the work of the Benevolent Fund and does so with the confident hope that members will continue their generous support of this worthy cause. Members who are not already subscribers to the Fund are asked to join and in that way help the Committee of Management in the work it undertakes for the fund during the year. During 1950 a sum amounting to £7310 was granted to eighty-two cases. As the Institution bears the cost of administering the fund practically the whole of each subscription received is applied to the allowances and grants. In connection with the latter the Committee of Management has been able to assist with the education of the children of deceased members.

Students' Aid Fund.—The Committee of Management considered a number of applications and recommended to the Council the payment of grants to nine cases, amounting to £339.

Model Conditions of Contract

The attention of members is drawn to the availability for purchase of the revised Model General Conditions of Contract (A), Home Contracts—with Erection, suitable for the mechanical and electrical engineering industries, the publication of which has been authorised by the Council and by the Council of the Institution of Electrical Engineers. Copies are on sale at a cost of 5s. each, post free, and may be obtained from the Secretary of either Institution.

The British Association

The 113th annual meeting of the British Association for the Advancement of Science is to be held in Edinburgh from August 8th to 15th next. This will be the sixth time the Association has visited Edinburgh for its annual meeting, the former occasions being in 1834, 1850, 1871, 1892 and 1921. The forthcoming meeting is being planned to form a part of the Festival of Britain, and many items in the programme will be concerned with contributions made by British science since 1851. The meeting will, in fact, be the principal "non-official" effort to present the progress of British science by means of lectures, addresses and discussions in which prominent scientists will take part.

H.R.H. The Duke of Edinburgh has consented to serve as President of the British Association this year. He will deliver his Presidential Address, entitled "The British Contribution to Science and Technology in the Past Hundred Years," at the inaugural general meeting in the McEwan Hall on Wednesday evening, August 8th. The meeting will be preceded by a special Graduation Ceremonial at which H.R.H. The Duke of Edinburgh will receive from the University of Edinburgh the honorary degree of Doctor of Laws.

The meetings of Section G, Engineering, will take place at the Heriot-Watt College, Chambers Street, Edinburgh. Sir Claude Gibb, F.R.S., is this year's President of the section, and his address, to be delivered on Friday morning, August 10th, will deal with "Two Thousand Years of Engineering." Among the subjects for discussion at the meetings of Section G are: "Problems in the Combustion and Slag Removal of High Ash Content Coal"; "Hydro-Electric Schemes"; "Printing"; "Heat Transfer"; "High-Tension Transmission," and "Metals and Alloys." There will also be a session for the discussion of a series of papers to be presented by young engineers.

As usual, several of the presidential addresses and discussions in other sections of the Association will be of considerable interest to engineers. In Section A, for example, there are to be discussions on "Surveys of Physics, 1850–1900 and 1900–1950," and "Nuclear Physics in Scotland," and Section L will discuss "Higher Technological Education" and "Technical Education in the U.S.A." Among the special evening discourses, which will be delivered in the Usher Hall, is one, on Friday, August 10th, by Professor John Read, F.R.S., on "Alchemy and Alchemists." The division of the Association which studies Social and International Relations of Science will hold an open meeting in the Pollock Hall on August 13th on "Social and International Aspects of Communications." It is hoped to deal, in particular, with the development of radio communications and of air travel and to consider their effects and implications in the modern world.

In addition to the lectures and discussions, there is an extensive programme of social functions and excursions to works and other places of technical and general interest. Sir Edward Appleton, F.R.S., is chairman of the local executive committee.

Report on Boiler Explosion at York Power Station

THE report of the preliminary inquiry into the explosion of a water-tube boiler at the Foss Island Power Station, York, on October 27, 1949, has just been published. As a result of this explosion one plant attendant was killed and six suffered from injury or shock.

In this power station, which was taken over from the City of York Corporation by the British Electricity Authority in April, 1948, there were two separate and independent plants. The low-pressure plant consisted of two 5000kW and one 3500kW turbo-alternators, supplied with steam at 200 lb per square inch and 600 deg. Fah. from four John Thompson and two Babcock and Wilcox boilers. The high-pressure plant consisted of one 20,000kW turbo-alternator, supplied with steam at 400 lb per square inch and 800 deg. Fah. from two John Thompson boilers. The explosion occurred at about 4.20 a.m. on October 27, 1949, in the low-pressure plant and involved boiler No. 1, a John Thompson "Alpha" six-drum water-tube unit, installed at the station in 1928, which was working at 200 lb per square inch.

The inspecting officer, Mr. J. G. Charlton, states in his report, that the explosion was of an extremely violent nature. The wrapper plate of the middle section water drum failed through the outer row of rivet holes for practically the whole length of the front longitudinal joint and was also torn through the rivet holes of both circumferential end seams for a distance of about 3ft 6in. The boiler was projected through the roof of the boiler-house and the tubes connecting the three sections were pulled out of the front and rear drums. The middle section was found 150ft distant and the front section was found 75ft away with the superheater alongside. The rear section of the boiler was projected in the opposite direction and came to rest on two overhead cranes which had collapsed in the engine-house.

When Mr. Charlton visited the scene of the explosion he found that in the middle section of the boiler, consisting of the two drums and interconnecting tubes, most of the circulating tubes remained attached to the steam water drum. The explosion had apparently tended to straighten out the wrapper plate, but subsequent contact damage had distorted and bent it at each end. The generating tubes had been forced inwards in both drums by the explosion and subsequent contact damage had caused eight tubes to be drawn from the steam-water drum and eleven tubes from the water drum.

The fractures between the outer row of rivet holes in the wrapper plate presented a blackened brittle appearance, except where damaged by contact with brickwork. Cracks radiated from most of these holes, especially on the dry side of the plate, and many cracks penetrated the thickness of the plate. A black oxide was observed in some cracks and also on the torn edge between the rivet holes. There were indications that the cracks had gradually progressed from the edge of the rivet holes on the dry side of the plate and extended inwards to join up with cracks from adjacent rivet holes. There was practically no plastic deformation of the fractured plate between the rivet holes, except at the extreme ends of the longitudinal joint and between the rivet holes at the torn circumferential seams.

The examination of the boiler and the mountings revealed no indication to suggest that either shortage of water or overpressure were contributory causes to the explosion. In the drum which failed, however, the appearance of the fractures in the longitudinal seam was in all respects similar to those associated with failures ascribed to caustic cracking. Mr. Charlton attributed the cause of the explosion to intergranular cracks, caused by the combined action of stress and chemical action, otherwise known as caustic cracking, spread from and between the outer row of rivet holes in the middle water drum wrapper plate until it failed under the working conditions.

In the conclusions to the report it is pointed out that stress-corrosion cracking is a term used to-day to denote cracking under steady unidirectional stress, as opposed to failure under alternating or fluctuating stress commonly referred to as fatigue. Under the microscope these two kinds of cracking are readily identified; stress-corrosion cracks being mainly intergranular and fatigue cracks being usually spearlike and transgranular. It is well known that intergranular failure may occur under a variety of conditions with various materials, but under the conditions obtaining in steam boilers intergranular cracking is always associated with chemical attack by concentrated solutions of sodium hydroxide, as no other constituent of the boiler water is ever present in sufficient quantity in itself to cause such attack. Such other constituents may act either as accelerators or as inhibitors, and in certain circumstances some may change from one role to the other.

In the dismantled joints considerable amounts of alkaline deposits were found, which consisted mainly of iron oxide and hydroxide together with sodium hydroxide, from which it was concluded that under conditions of evaporative leakage a wide range of concentration of caustic soda could have been set up in the joint during service.

There was ample evidence to indicate that the cracks initially commenced at the edges of the rivet holes on the dry side of the wrapper plate of the middle water drum, and in the case of the butt straps from the edge of the rivet holes on the inner surface of each strap. These positions were probably coincident with points of maximum localised stresses in the material, and in contact with concentrated sodium hydroxide would create the conditions necessary to initiate the form of cracking which resulted in the failure of the drum. The first visible indications that such an action may have taken place within a riveted joint is by rivet heads falling off, or at certain stages by persistent leakage. No such warning indications were observed in the case of the drum which failed, and a careful examination after the explosion revealed one rivet head missing and indications of only very slight leakage at four rivet heads. That there were such slight external indications from a joint, that must have been severely cracked for practically the whole length of the drum, must be a matter of grave concern to those responsible for the maintenance of boilers.

Another drum of the No. 1 boiler did, however, in the light of subsequent events, give unmistakable warning. This was the front steam-water drum in which, owing mainly to the greater evaporation in this section of the boiler, the highest concentration of dissolved solids in the boiler water might be expected. From a number of defective rivets found in both longitudinal joints in 1947, caustic cracking was in fact suspected, but those responsible for the examination of the boiler were not convinced that the cracks discovered in the butt straps were caused by caustic cracking. The history of the boiler, it is stated, only emphasises the necessity to heed the slightest indication of leakage from riveted joints, and to take such measures as are necessary to ascertain the cause.

Commenting upon the report and its conclusions, the Engineer Surveyor-in-Chief mentions two similar cases of boiler explosions attributed to caustic cracking and states that if there was any hesitation thirty years ago on the part of engineers to accept caustic cracking as the serious destructive agent it has been proved to be, there is none to-day; and also that caustic cracking is not associated solely with conditions of high pressures and temperatures, because in none of the cases mentioned did the pressure exceed 200 lb per square inch.

The surveyor-in-chief goes on to say that it may not be significant that in the three cases compared no one boiler was less than twenty years old, but it does establish that immunity from this action may never be assumed. It is more important, however, to compare these three cases, because in each there is a suggestion that caustic cracking may take place without signs ordinarily detectable. It is disturbing to know that there were few outward signs from the seam that failed in the present instance, and it must now be asked if there were no indications anywhere that might have engendered suspicion that some abnormal action was taking place; the answer must be that tangible evidence was not lacking. That the abnormality was indeed caustic action was actually suspected but was rejected as untenable; that it could be nothing else than caustic action was only apparent after the explosion, and the value of this inquiry and report will be great if, as a result, such fateful signs are correctly diagnosed in future. It would, however, be unreasonable to suggest that because the signs present were wrongly interpreted, blame could be imputed to any one person or group of persons. The phenomenon of caustic cracking has become familiar to engineers, and an inclination to use the term to account for defects produced by bad workmanship has been noticeable on more than one occasion. Cases in which rivets have developed an alarming tendency to shed points or heads, and in which caustic soda had no part, are by no means unknown, and in looking at the present case it may be equitable to keep that in mind; nevertheless, the surveyor claims, it is important that the cause of even the slightest leakage from a riveted joint should be investigated.

If certain detection is imperative, prevention is not less so, and the correct treatment of fresh water for boilers having riveted drums assumes an increased importance. Much has been done in this direction, as is indicated by the conclusions offered in a publication by the British Standards Institution, Standard No. 1170 of 1947, and also in the Iron and Steel Institute's Special Report No. 41/1949, entitled "Corrosion of Iron and Steel by Industrial Waters and its Prevention." The importance of regular chemical tests of the boiler water and of the necessary control of alkalinity is apparent from the foregoing report.

It must be accepted that the fabrication of a riveted seam in which the stresses will be constant and low, and in which the faying surfaces are so perfectly closed as to prevent seepage into the seam, is not commercially possible, but nevertheless care in preparing and assembling such a joint and the caulking of inside edges may do much to combat the searching quality of sodium hydroxide.

DIAMOND JUBILEE BOOK.—To celebrate its diamond jubilee, which it attained last year, the Royal Dutch Petroleum Company has published a book reviewing the history of the company. The opening chapter gives glimpses of the past sixty years, tracing the growth of the business and mentioning that both the silver and golden jubilees coincided with European wars and so could not be celebrated. Exploration work is described and a chapter traces the development of the drilling equipment and the various production methods employed. The next section discusses processing, starting with the first refinery (1892) and describing the progress made—including the development of catalytic cracking, due to the demand for high octane fuels, and the production of lubricating oils. In recent years there has been an expansion in the petroleum chemical industry and the book mentions the manufacture of solvents and basic materials for various forms of plastics. The important part played by transport is described, reference being made to the growth of the tanker fleet and to the laying of pipelines. The work of the research teams is appraised and there is a description of the expansion and organisation of the marketing arrangements. The last chapter is devoted to the company's personnel and describes the organisation of staffs and the provision made for their comfort at the various stations. Numerous photographs illustrate the text and cover all aspects of the company's activities.

The Air-Cooled Deutz Diesel Engine

APART from aero-engines which, by the very nature of their cylinder arrangement and their mountings, provide particularly favourable cooling conditions, the air cooling of internal combustion engines, up to the beginning of the second World War, has been almost entirely confined to small industrial and motor-cycle engines of not more than 500c.c. capacity per cylinder. During the war a number of air-cooled diesel engines were developed in this country, the Continent and in the U.S.A., mainly on the instigation of the military authorities, who wanted small and light self-contained engines developing from 6 h.p. to 15 h.p. for driving generators, pumps, concrete mixers, &c. The specifications demanded that these engines, which usually consisted of one or two cylinders with a maximum speed of about 1750 r.p.m., should work with a minimum of service and maintenance, be independent of any water supply and operate under extreme climatic conditions.

Because of the greater excess air and the longer expansion ratio of the diesel engine, the temperature of the cylinder head and the cylinder walls is lower than that of a petrol engine of the same bore, and once a way had been found of sufficiently cooling the injector, the development of these air-cooled engines presented less difficulty than was originally anticipated. To-day several thousand small industrial air-cooled engines are running satisfactorily in many parts of the world.

However, the adoption of air-cooled diesel engines for road transport purposes has so far been apparently neglected, although the advantages of air cooling seem to be much more pronounced in this particular field of application than in stationary plant. Assuming, as is reasonable nowadays, that the air-cooled engine can be built to give about the same output as the water-cooled machine for the same constructional effort, it is superior to the latter by virtue of its smaller weight, greater simplicity and reliability, there being no radiator, water jacket, circulating pump, pipes, rubber joints, or thermostat, and, consequently, no corrosion or freezing troubles. Furthermore, there can be no evaporation losses when running in hot weather at high altitudes. The overheating of air-cooled engines in these circumstances is less likely to take place, as the quantity of air delivered by the blower rises more quickly than that actually required for adequate heat dissipation.

However, an air-cooled diesel engine is definitely noisier than its water-cooled counterpart. Owing to the higher mean temperatures, resulting in greater expansion of the cylinder barrels, the clearances of pistons and cylinders and of cams and tappets have to be bigger, and thus the noise caused by these parts is more pronounced than in water-cooled engines, in which the water jacket acts as a very efficient sound damper. The noise of a modern high-speed blower is appreciably more audible than that of an ordinary radiator fan. Extensive efforts are still being made to reduce the noise generated by these causes to a tolerable level,

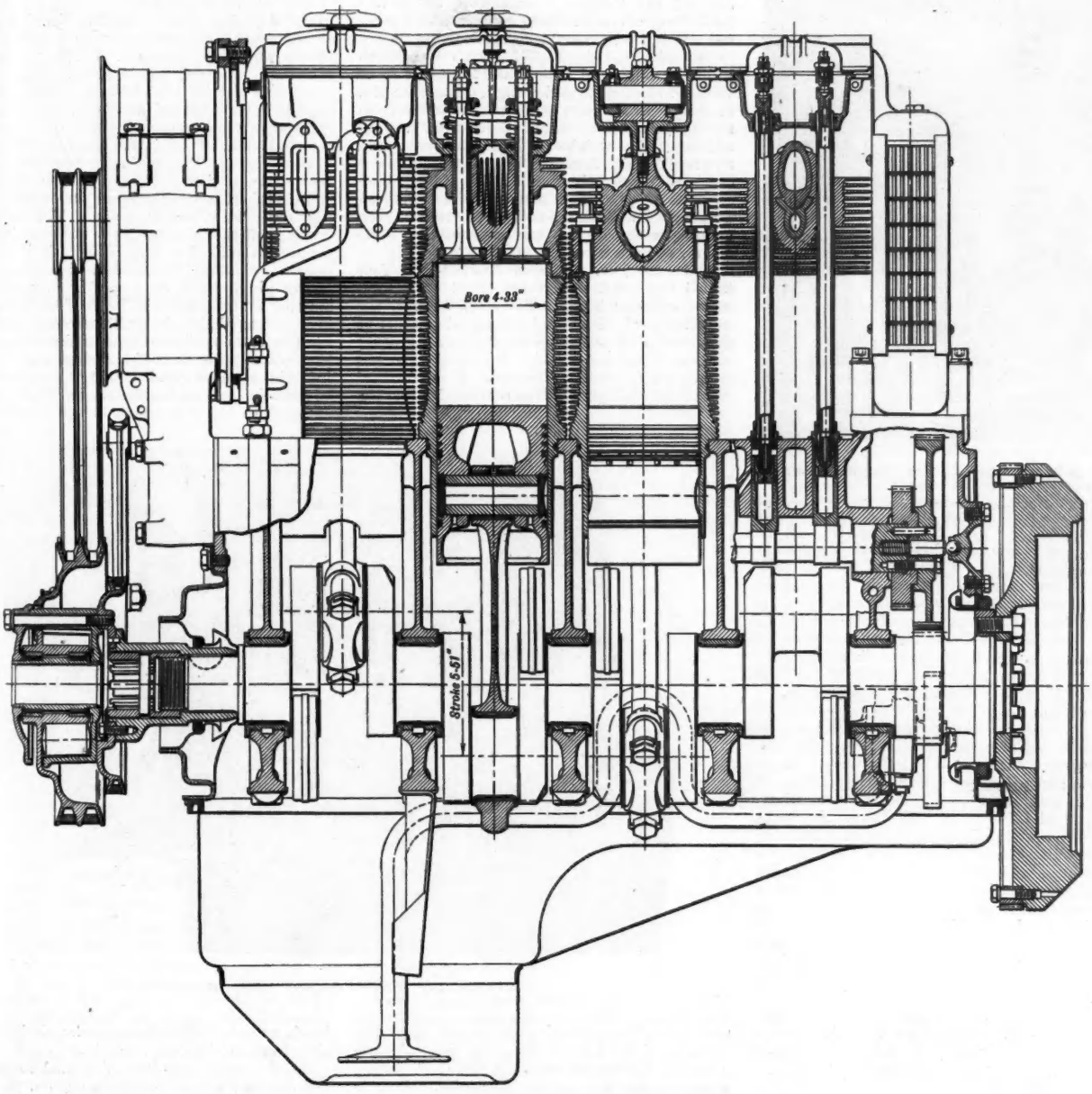


FIG. 1—LONGITUDINAL SECTION THROUGH ENGINE

and in the last ten years some progress has been made.

We had the opportunity recently of visiting the works of Kloeckner-Humbold-Deutz A.G. in Cologne and saw its air-cooled four-cylinder diesel engine in the course of manufacture and on the test bed. This engine, although not actually the first one especially designed for use in road vehicles—a 50 h.p. air-cooled diesel engine of 4·1 litre capacity, made by A. Krupp A.G., Essen, was exhibited in 1933 at the Berlin Motor Show—is, to our knowledge, at present the only one which is built in large numbers.

Historical Account.—An interesting account of the historical development of the Deutz

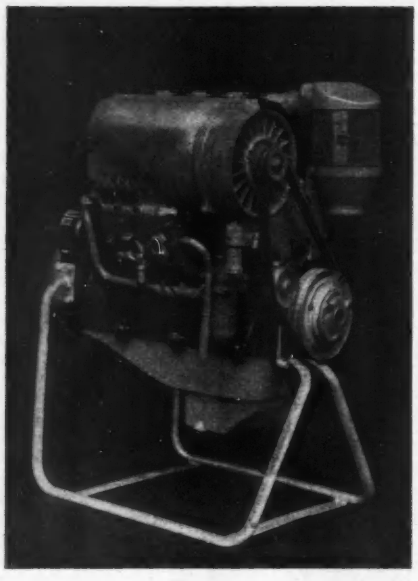


FIG. 2—75 H.P. AIR COOLED DIESEL ENGINE

engine has been given in the *Motortechnische Zeitschrift*, Vol. VII, No. 3, by Dr.-Ing E. Flatz, the managing director of the Deutz Engine Works. Dr. Flatz noted that in 1942 his firm was faced with the task of equipping 3-ton diesel lorries with air-cooled engines. It is known that at the same time other German firms also started experimenting with air-cooled engines, as a result of serious difficulties encountered with motorised transport in the severe cold of the Russian winter campaign.

The Deutz Engine Works first converted two existing water-cooled engines to air cooling, the 5-litre four-cylinder engine of a 3-ton lorry and the 7·5-litre engine of a 4·5-ton lorry. Both engines had a bore of 110mm and a stroke of 130mm and developed (with fan attached) 80 h.p. and 120 h.p. at 2250 r.p.m. As far as possible use was made of the various components of the water-cooled engines, and the majority of castings, with the exception of the cylinder heads, were produced from existing patterns with only minor alterations. Re-designing the cylinder head provided the opportunity of replacing the precombustion chamber of the water-cooled engine by a new swirl chamber, which, some years previously, had been tested in some experimental cylinders and had given satisfactory results. By the adoption of this new combustion chamber it was found possible to reduce the fuel consumption by about 10 per cent and to attain easy starting at low temperatures.

The first engines were running on the test bed within four months, and the four-cylinder engine, which had been given first priority, developed almost from the beginning the required output of 70 h.p. at 2250 r.p.m. In spite of the uncertainty of estimating the necessary area of the cooling surfaces as well as the volume and the pressure of the cooling air delivered by the blower, the results proved to be most satisfactory. A further year of extensive detail work ensued until the engine could meet the severe acceptance conditions, which included that of starting at temperatures around −40 deg. Fah.

On completion of the actual development work modified specifications called for an increase of the rated horsepower from 70 h.p. to 75 h.p. This was done by the expedient of lengthening the stroke from 130mm to 140mm, thus raising the capacity of the four-cylinder engine to 5·3 litre. The weight of the engine at the end of the development period was 1047 lb with all accessories attached, the weight/power ratio 14 lb per h.p. and the specific output 14 h.p. per litre.

Manufacturing conditions in Germany towards the end of the war made it impossible to produce the new engines in great numbers; but, in spite of these difficulties, more than 1000 were fitted into 3-ton lorries built by the Magirus A.G., a sister company of the Deutz Engine Works. The results achieved with these military vehicles under arduous conditions induced the Magirus Company to adopt air-cooled engines as standard equipment for commercial and public service vehicles.

General Lay-out.—Fig. 1 shows the longitudinal section and Figs. 2 and 3 present other views of the four-cylinder engine, Mark FL514, in its present form (1950), which differs from the prototypes in small details only. By reducing the weight of the crankcase and flywheel and, further, by replacing some castings (blower, blower bracket, inlet manifold, &c.) by welded pressed steel constructions it has been possible to reduce the overall weight of the engine from 1047 lb to 892 lb, equivalent to less than 12 lb per h.p.

The cast iron crankcase carries the four finned cylinders, which are fitted with light metal cylinder heads. The axial blower, the impeller shaft of which is arranged parallel to the crankshaft axis, is positioned on a bracket in front of the engine and is driven by a vee belt from a pulley, flexibly mounted on the forward end of the crankshaft. The air duct leading the cooling air from the blower to the cylinders is made of sheet steel and can easily be removed. A rear extension of the duct directs some cooling air to the oil cooler, which is mounted on the flywheel end of the engine, immediately behind the fourth cylinder. The induction-hardened crankshaft is supported by five lead-bronze main bearings; it carries at the rear end the spur wheel for the camshaft drive and on the front end the pulleys for driving the blower and the generator.

The short connecting-rods ($l/r=3·9$) are split at the big ends at an angle of 45 deg. to the centre line in order to allow the rod and piston assembly to pass through the cylinder. The rods are fitted with lead-bronze steel-backed bearings and phosphor-bronze bushes for the small ends. Overhead valve gear is employed and operated by push rods; it is totally enclosed and lubricated from the oil pump. The fuel injection equipment was made by Bosch; the injection pump is arranged in a slightly inclined position below the air duct, and it has been found that no timing device was necessary.

Cylinder Head.—The cylinder head is a heavily finned die casting of low-expansion aluminium alloy. In order to facilitate the moulding and casting process the valve gear casing is a separate part, made of cast iron and bolted to the cylinder head; a detachable cover of sheet metal protects the rocker gear. The pear-shaped swirl chamber (Fig. 4), the volume of which comprises about 60 per cent of the total compression space, is also made of cast iron and is cast integral with the aluminium head. It is removed to one side of the cylinder and the throat enters the swirl chamber at an angle of about 30 deg. to the cylinder axis. With this arrangement it is possible to accommodate large valves and thus maintain a high volumetric efficiency over the whole speed range. The injector is also inclined relative to the cylinder axis and is positioned at the inlet end of the cylinder cowling in such a way that it receives the full flow of cold air entering from the blower duct. The main proportion of the fuel spray is directed towards the throat of the chamber, a small proportion only impinging on the chamber walls. The efficient cooling of the injector and the self-cleaning properties of the single-hole pintle nozzle prevent choking by carbon deposits. The heater plug, which as a rule is only used for starting at temperatures below freezing point, is so arranged that it is not adversely affected by the attack of the hot combustion gases. The valve guides are of cast iron and pressed into the cylinder head, whilst the valve seats, of special cast iron, are shrunk in. The cylinder head, together with the cylinder, is bolted to the crankcase by four long studs.

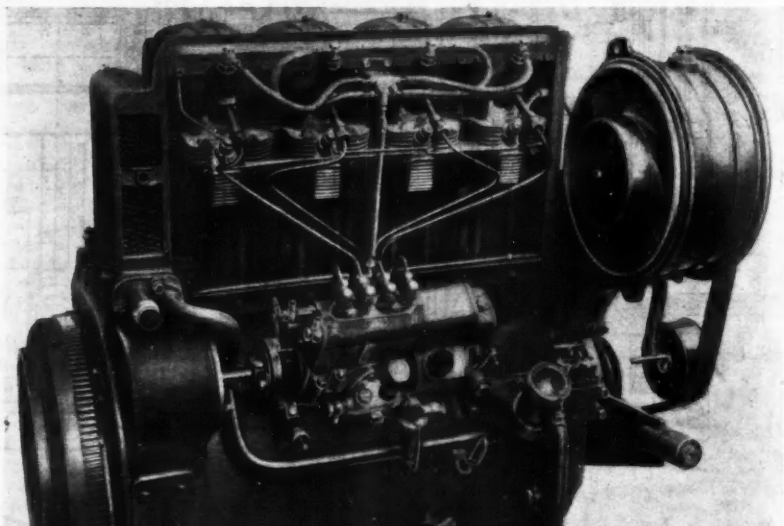


FIG. 3—ENGINE WITH COOLING DUCT REMOVED

As the engine has been designed to be convertible into a spark-ignition engine, the swirl chamber can be cut off by means of a plug inserted in the slightly tapered chamber passage and tightened by a bolt screwed into the bore for the heater plug.

Cylinder and Piston.—The cylinder, the outside of which is machined all over, has a great number of circular fins, stretching over the whole length of the stroke. It is tightly fitted on to the cylinder head so that both these parts can be removed from, and assembled on, the crankcase without any risk of damage to the cylinder head gasket.

As the cylinder distance of the air-cooled engine is the same as that of the water-cooled engine from which it was originally developed, part of the fins between the cylinders had to be cut off considerably. The total cooling surface therefore is somewhat reduced, but although the rate of heat dissipation from the cylinder walls is not constant over the whole circumference, cylinder distortion is kept well within tolerable limits.

The piston, of aluminium-silicon alloy, has a flat crown and is provided with three pressure rings and two stepped scraper rings, one above

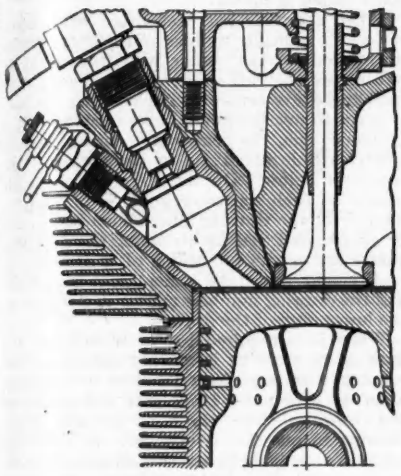


FIG. 4—COMBUSTION CHAMBER

and one below the fully floating gudgeon pin. The piston clearance, amounting to 0·0043in in the water-cooled engine, has been increased to 0·0071in to suit the higher mean temperatures. No special piston rings or ring carriers were necessary to ensure reliable continuous operation.

Blower.—At maximum load the four-cylinder engine requires an air volume of 152,000 cubic feet and the six-cylinder engine 230,000 cubic feet per hour for cooling, the pressure produced by the blower amounting to 55·3 lb per square foot in each case. An axial blower was chosen, as this type combines simplicity in design with reasonable efficiency, and offers favourable conditions for smooth air flow and good air

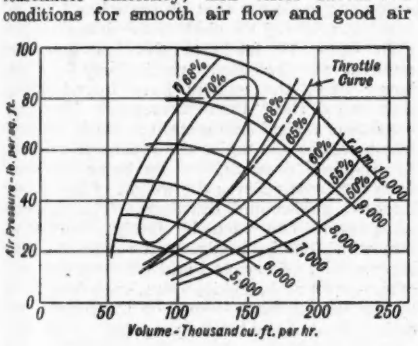


FIG. 5—CHARACTERISTIC CURVES OF BLOWER

distribution with a minimum of constructional effort. The blower, secured on a bracket at the front of the engine by means of steel tapes, is driven by a vee belt from a pulley on the crankshaft. A spring-loaded idler pulley, fitted with an oil damper, serves as belt tensioner.

Fig. 5 shows some characteristic curves of the blower fitted to the four-cylinder engine. The contours of constant efficiency show that an efficiency of 70 per cent can be maintained over quite a considerable speed range. The throttle curve in Fig. 5 indicates the behaviour of the blower when mounted on and tested in conjunction with the engine; the efficiency remains practically constant at 68 per cent for blower speeds between 5000 and 10,000 r.p.m., equivalent to engine speeds of between 1500 and 2700 r.p.m. The blower for the six-cylinder engine differs from that of the four-cylinder engine only by having an impeller and a guide vane annulus of bigger diameter. The characteristic curves are similar, but as the influence of wall friction is less pronounced in the larger blower, a maximum efficiency of 75 per cent can be attained over a speed range of about 6000 to 8000 r.p.m.

The air flow from the blower is conducted to the cylinders by a tapering duct made of sheet metal. No deflector plates, which may cause a pressure drop, are employed inside the duct, but guide plates attached to the cylinders ensure a satisfactory air distribution.

In this connection it is worth mentioning that the power required for driving the blower of an air-cooled engine is much smaller than generally assumed. Fig. 7 shows the power absorbed by the blower of the air-cooled engine in comparison with the power required by the water pump and the fan of water-cooled engine. Contrary to an opinion widely held, the power absorbed by the fan and the water pump over the whole speed range is practically the same as that required by the blower of the air-cooled engine.

Oil Cooler.—The intensity of the heat flow, and therefore the main temperature of the air-cooled engine, is, of course, higher than that of the water-cooled engine, as the surfaces available for heat dissipation are one-fifth of the latter, and a great amount of heat is convected to the lubricating oil. In a lorry operating under normal conditions the oil temperature of the air-cooled engine, as a rule, does not exceed 195 deg. Fah., but precautions had to be taken against excessive oil temperatures, and an oil cooler has been fitted on the crankcase behind the fourth cylinder, which receives a flow of cooling air from the blower through an extension of the air duct.

In order to prevent damage to the cooler tubes by excessive oil pressure, i.e., when starting the cold engine at very low temperature, a spring-loaded by-pass valve has been provided.

Test Bed Results.—The fuel consumption of the prototype engine Mark FL513 (130mm stroke) is shown in Fig. 6. The optimum consumption of the four-cylinder engine was 0·407 lb per b.h.p.-hour at 1100 to 1200 r.p.m., rising to 0·418 lb per b.h.p.-hour at 1700 r.p.m. (three-quarter full speed). The consumption of the six-cylinder engine was between 0·011 lb and 0·017 lb per b.h.p.-hour lower than that of the four-cylinder, most probably because of its higher mechanical efficiency. In order to give a general idea of the heat flow to the cylinder head two rather significant temperatures have also been plotted in Fig. 6. One is the temperature of the fins between inlet and exhaust ports, which, as ascertained by a great number of temperature readings, is the maximum temperature of the cylinder head, and the other curve shows the temperature of the swirl chamber in the immediate vicinity of the injector, which indicates the maximum temperature of the nozzle seat. Both temperatures were measured by means of caulked-in copper-constantan thermo-couples. The curves show that the temperature of the cylinder head falls with increasing engine speed if the load changes with the cut-off of the governor. The highest thermal strain to which the engine is subjected coincides with the maximum output, and not, as in the majority of air-cooled petrol engines, with the maximum torque. As the maximum engine speed, however, can always be kept safely under the control of the governor, overheating of the engine is unlikely to occur. It should be mentioned that the governor is so adjusted that over the whole speed range the controlled maximum mean effective pressure is always kept below the smoke limit.

Fig. 8 shows performance curves of the four-cylinder Mark FL514 (140mm stroke) taken after the official 100-hour non-stop test. The torque curve is noticeably flat and the mean effective pressure has its maximum value at the clean exhaust limit with 98 lb per square inch at 1500 r.p.m. The fuel consumption of 0·420 lb per b.h.p.-hour remains practically constant between 1000 and 1700 r.p.m., which is within the range most widely used under actual road conditions.

The fuel consumption of the engine may not appear very impressive when compared with that of modern direct injection engines, where consumptions down to 0·360 lb per b.h.p.-hour have been measured. It should be remembered,

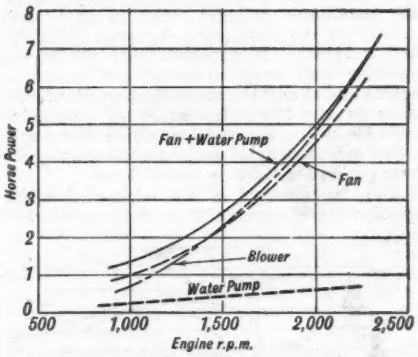


FIG. 7—CHARACTERISTICS: COOLING AUXILIARIES

however, that other Continental and American diesel manufacturers also favour engines with subdivided combustion room for use in road vehicles, for a variety of reasons, in spite of their higher fuel consumption. They claim that it is easier to attain a high volumetric efficiency and mean effective pressure at clean exhaust limits, especially in small cylinders. They maintain also that the single-hole nozzle is likely to give less trouble than the multi-hole nozzle of the direct injection engine and, furthermore, precombustion chambers, swirl chambers and air cells are mostly insensitive to different grades of fuel, thus running for longer periods without attention.

Extensive tests were carried out with the air-cooled four-cylinder and six-cylinder engines on the test bed, as well as on the road, with fuels widely different in viscosity, specific gravity and cetane number. Apart from the usual grades of commercial gas oil, other fuels, such

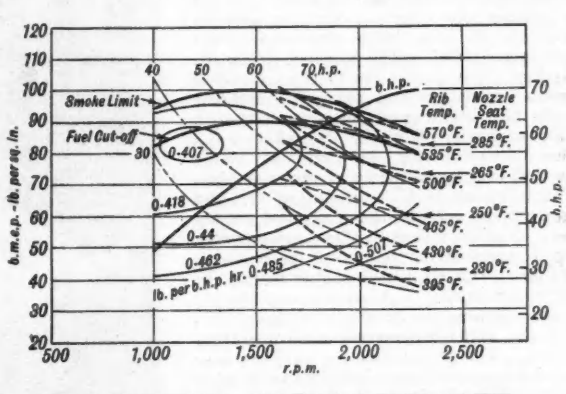


FIG. 6—CONSUMPTION AND TEMPERATURES OF THE FOUR-CYLINDER ENGINE

as lignite, tar oil, shale oil, paraffin and petrol with a 3 per cent admixture of lubricating oil, were used. With all these fuels the rated output could be maintained at clean exhaust, without the necessity of altering the injection timing. Supplementary tests were also made with two engines, converted to spark ignition, and running on petrol and producer gas. In these tests the swirl chamber was blocked off, the injection pump was replaced by a magneto, and new pistons were fitted to reduce the compression ratio, which, in the diesel cycle was 18·5. The following results were achieved:—Petrol: compression ratio, 5·9; output, 75 b.h.p.; fuel consumption, 0·540 lb per b.h.p.-hour. Producer gas: compression ratio, 8·5; output, 55 b.h.p.; fuel consumption, 10,700 B.Th.U. per b.h.p.-hour.

Road Tests.—Road tests were carried out with two air-cooled diesel engines fitted into 3-ton Magirus lorries, the total distance travelled by each lorry exceeding 75,000 miles. Parallel tests were made over the same distance and under similar operating conditions with other lorries fitted with a water-cooled diesel engine and with air-cooled engines running on producer gas. After completion of these tests the engines were examined; the tests were then continued for some time after new piston rings had been fitted. The wear measured after 75,000 miles was found to be practically identical in the air-cooled and in the water-cooled engine, the maximum cylinder wear in each case amounting to something between 0·0110in and 0·0118in. It appeared that the higher cylinder wall temperature of the air-cooled engine had almost the same effect upon cylinder wear as the low temperature of overcooled cylinder walls, a condition which frequently exists in water-cooled engines when running for long periods at light or partial load.

The examination of the air-cooled spark ignition engine running on producer gas showed

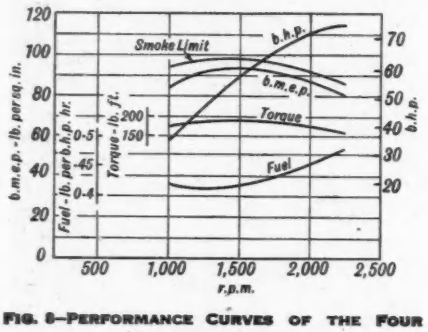


FIG. 8—PERFORMANCE CURVES OF THE FOUR CYLINDER ENGINE

very different results; the cylinder wear was very much smaller than that of the diesel engines, and operation could be maintained for 180,000 miles before overhaul. This, of course, was partly due to the lower thermal and mechanical stresses to which the engine was subjected, but it also seems to indicate that the cylinder walls of the gas engine are immune from the corrosive effect of fuel condensation, and that for the same reasons the lubricating oil is not affected by crankcase dilution.

To minimise the effect of corrosion and oil dilution all the later-built air-cooled diesel engines were fitted with positive crankcase ventilation. It is partly due to this improved crankcase ventilation and partly to modified materials with better wear characteristics that to-day the cylinder life of the air-cooled engine between reconditioning intervals is about double that of the pre-war water-cooled engine.

A contributing factor accounting for the better cylinder wear of the air-cooled engine might be its relative insensitivity to the greatly increased sulphur contents of present-day diesel fuels. The air-cooled engine warms up rapidly after starting and maintains a favourable mean temperature even at very light load; the cylinder wall temperature, in all operating conditions, is high enough to prevent any appreciable condensation of sulphur trioxide in the form of sulphuric acid, thus eliminating one of the causes of cylinder corrosion and oil contamination.

Behaviour at Extreme Temperatures.—Water at extreme temperatures is not an ideal cooling agent, due to the risk of freezing and evaporation. It was to be expected that the air-cooled engine would work satisfactorily at low atmospheric temperature, whereas its behaviour at very high temperature was not so easy to predict. In numerous tests with temperatures down to —14 deg. Fah. starting could generally be accomplished after preheating the swirl chambers for one minute by means of the electric heater plugs. At lower temperatures, however, the engine had to be warmed up by an air heater. This heater, in principle, consists of a series of guide plates which conduct a current of hot air from a blowlamp towards the discharge end of the cooling air duct, thus warming up the cylinders and cylinder heads. At an air temperature of —40 deg. Fah. the engine could be started after application of the blowlamp for ten minutes and preheating the swirl chambers for one minute. It took about five more minutes for the engine to arrive at a safe operating temperature, i.e., one which eliminated any risk of dilution of the lubricating oil. The total time required to start the engine from cold until the vehicle is ready to move off is only one-third of that necessary for a water-cooled engine under these conditions.

At high temperatures the air-cooled engine also proved to be very efficient and most reliable. In a two-hour test the engine was run at full speed and full load under an ambient temperature of 140 deg. Fah, and no excessive overheating or damage to bearings, piston rings, &c., occurred, although the temperature of the lubricating oil rose to 220 deg. Fah.

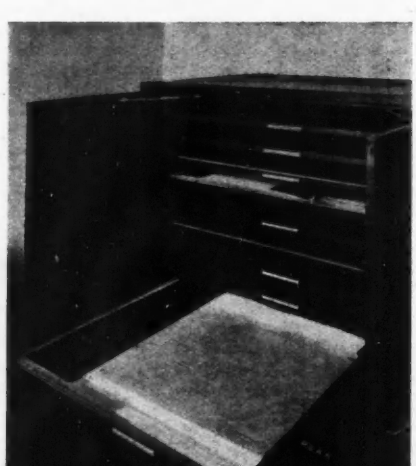
The road tests showed that servicing the air-cooled engine is in no way different from that of the water-cooled engine, and maintenance work is simplified as the separate cylinders and cylinder heads can be more easily dismantled and assembled than in a multi-cylinder block.

It is thought that the air-cooled diesel engine will probably be restricted to small cylinder bores and to mean effective pressures not exceeding 100 lb per square inch.

Since the end of the war (up to the end of 1950) about 15,000 air-cooled engines have been built, the majority by the Magirus A.G., Ulm. Apart from the four-cylinder and six-cylinder engines described above, an eight-cylinder V engine of 150 h.p., of the same cylinder dimensions and the same basic design, is also being built.

A Filing Unit for Drawings

A NEW filing and storage system for drawings, plans, tracings, &c., which has been introduced by Plandex, Ltd., Naas Road, Inchicore, Dublin, Ireland, can be fitted in the drawers of existing office equipment or supplied as a complete unit in a metal cabinet, as illustrated on this page. This system has been developed



DRAWING OFFICE FILING UNIT

to make possible the rapid insertion and withdrawal of sheets without damage and has a particular advantage in that the creasing or curling of print edges, such as is often caused by "corner thumbing," is avoided. It can be used for the storage of prints up to double elephant size, and up to 100 drawings of various sizes can be filed in each drawer of a storage cabinet.

Two principal units are used in each drawer laid out under the "Plandex" filing system—a spacer rack and a set of 100 separator guides. The spacer rack, which is fixed along the bottom at the back of the drawer comprises a moulded bar of strong plastic material having projecting upwards from it a series of pegs $\frac{1}{16}$in diameter, $1\frac{1}{4}$in high, and spaced at intervals of $1\frac{1}{4}$in. These spacer racks are made in units 13in long and they can be assembled end-to-end according to the width of the drawer. The separator guides are strips of heavy manilla paper $4\frac{1}{8}$in wide and they are made in various lengths up to 32in to suit the width of the filing drawers. A line of holes spaced at $\frac{1}{8}$in centres is punched across the full width at the upper end of each separator guide and its bottom left-hand corner is cut off.

When a drawer has been fitted with spacer racks, the requisite number of separator guides are placed on the spacer pins from right to left across the full width of the drawer. As each successive separator is placed on the rack it is set to overlap about three-quarters of the previous one, its cut-away corner leaving clearly visible about $\frac{1}{2}$in of the corner of the separator below. On the space which is left visible on each separator guide is printed the number of the drawing filed above it. It will be appreciated that by arranging the separator guides across the full width of a drawer, the total height they take is kept to a maximum, and the drawing numbers appear in a line along the lower edge of the drawer.

When it is required to file or to remove a drawing its position is quickly ascertained by running a thumb along the line of numbers. Then, by lifting that guide with the separators and drawings above the filing position of the drawing in question is exposed. As drawings are laid loosely between the separator guides and are not locked or clipped in any way, their insertion and removal is quickly and easily effected.

A further feature of this system is that it incorporates a means of permanently recording the dates when drawings are inserted and removed, and the person responsible. This record is kept by entries made in a series of columns printed on the lower half of each separator guide. The columns are headed "In" and "Out," and provide "boxes" in which the date and initials of the person handling the appropriate drawing can be entered. The possibility of filing drawings in the wrong place is considerably reduced as only one sheet is filed under each guide. An attempt to file a second sheet in a space already occupied by a drawing indicates that an error has been, or is being, made by the clerk or the draughtsman.

In order to facilitate the insertion and removal of drawings, particularly of the larger sizes, the makers have introduced a unit called the "Plandextractor." The unit consists of a rigid thin metal or plastic "slice," which can be slid under the separator guide of the required drawing, and on being tilted up from the front relieves the weight of the superimposed guides and drawings. The drawing in question can then be freely inserted or removed. The back edge of the extractor unit is serrated to fit around and between the pegs of the spacer rack, and its operation is facilitated by the sloping faces formed on the base of the rack in front of and behind the pegs.

INCREASE IN ELECTRICITY CHARGES IN SCOTLAND.—The North of Scotland Hydro-Electric Board has announced that because of the rising cost of materials and labour, it has been compelled to increase its charges for electricity by 10 per cent. No consumer, however, will be charged a higher average price than 6d. per unit, which is the present maximum. The Board introduced new tariffs in December, 1948, which resulted in a reduction of charges in some areas, and last winter a cheaper rate at $\frac{1}{2}$d. per unit was introduced in the main part of its area. There has been, however, a steady rise in the cost of materials and labour required for the production and distribution of electricity. The increases which have taken place between December, 1948, and March, 1951, the Board states, have been for copper wire, 43·1 per cent; aluminium, 42·5 per cent; cement, 14 per cent; wood poles, 62·1 per cent; diesel oil, 24·5 per cent, and coal 10 per cent. The wages of manual labour in the electricity supply industry have increased by 11 per cent, and there have been steep rises in the cost of manufactured plant and machinery.

Industrial and Labour Notes

Magnesium Supply and Distribution

The Ministry of Supply is to assume responsibility for the supply and distribution of all virgin magnesium in the United Kingdom from May 1st. To enable an assessment to be made of industrial requirements, consumers of virgin magnesium have to provide information as to their stocks on March 31st, their consumption during the first quarter of this year, and their estimated requirements in April and May. Known consumers have been provided with a form for the return of this information, but any users who have not received the form are asked to apply for it to the Ministry of Supply (M.2 Branch), Room 948, Shell Mex House, Strand, London, W.C.2.

During the current month, the Ministry says, consumers can obtain their magnesium supplies, as far as stocks permit, from Magnesium Elektron, Ltd., Clifton Junction, Manchester.

Non-Ferrous Metals

The Ministry of Supply says that the monthly announcements about copper, lead and zinc allocations, which have been made to industry since the beginning of this year, are to be suspended. In future, announcements will be made only when there is a significant change in the supply position, or when a major change is contemplated in distribution methods or the basis of allocations. No such change is planned for April in the case of copper and zinc.

Because of shipping problems, the lead supply position has become more difficult, but no change is to be made in the basic allocation of lead to consumers. They may purchase from the Directorate of Non-Ferrous Metals, Rugby, a quantity not exceeding 90 per cent of their average monthly consumption in 1950. The 90 per cent allocation, however, will represent the limit of deliveries of imported virgin lead, and orders placed for delivery in April will be taken into account and set off against the quota. Undelivered tonnage outstanding against contracts—even though it represents undelivered quotas for previous months—will be "frozen" until lead supplies permit the contracts to be honoured. Until further notice, purchases of imported virgin lead beyond the current month will be restricted to one month ahead.

The Ministry emphasises that the stated allocations of virgin copper, lead and zinc are only to firms which are first-line users—that is, those firms which habitually buy direct from the Ministry. These firms, of course, will not necessarily distribute their products to customers at the same percentage rates, but may have to vary allocations according to the importance of their customers' products. They will also have to vary the rates of distribution according to the availability of scrap or secondary metal.

On Monday last, the Board of Trade announced that, on account of the extreme scarcity of copper and zinc, the rate of export of semi-manufactures of copper and copper alloy is to be limited this quarter to approximately half the rate prevailing in the first six months of last year. All applications to export will be considered on their merits, and careful attention will be given to "conversion value," to the established pattern of trade, and to the importance of the end use. The export of semi-manufactures of zinc, the Board states, will be permitted only in exceptional circumstances.

Non-Ferrous Metal Prices

At the end of last week the Ministry of Supply announced increases from April 1st in the prices of copper, lead and zinc, as sold by the Directorate of Non-Ferrous Metals. The new prices per ton, delivered buyers' premises, are as follows, the old prices being shown in parentheses:—Electrolytic copper, £210 (£202); good soft pig lead, £160 (£136); good ordinary brand zinc, £160 (£151).

Discounts and premiums, and charges for forward delivery—where applicable—remain unchanged. The Ministry's buying price for rough copper is also unchanged. The Ministry says that the increased lead and zinc prices are necessary because of the higher prices it now has to pay for some of its supplies. The higher price for copper is attributed to increased costs such as freight and handling charges.

Maximum prices of non-ferrous scrap have also been revised to bring them into line with the new selling prices of virgin copper, lead and zinc. The new prices are authorised by the Non-Ferrous Metals Prices (No. 3) Order, S.I. 1951, No. 550, which came into operation on April 4th.

Index of Industrial Production

The index number of industrial production (1946=100) in the United Kingdom, which is prepared by the Central Statistical Office, has been estimated provisionally at 141 for January, compared with a revised figure of 139 for December, 1950. Figures for the corresponding months a year earlier were 135 for January, 1950, and 131 for December, 1949. The January, 1951, figure for the manufacturing industries only has been estimated at 147, compared with 138 in January, 1950. On the basis of information so far received the index for all industries for February, 1951, is expected to be 146 or 147.

The Central Statistical Office says that the provisional figure for January and the early estimate for February suggest that the rate of increase in those two months over a year ago was about 5 per cent for all industries, compared with an increase of 8¼ per cent in 1950 over 1949. One reason for the decline in the rate of increase, it is stated, was that building and contracting were well down, probably as a result of weather conditions. Shortage of raw materials may have been a contributory factor, but the Statistical Office thinks it is too early to say to what extent.

Average Weekly Earnings and Hours

Twice a year the Ministry of Labour collects from various industries in the United Kingdom information as to the weekly earnings of their workpeople and the number of hours worked. The latest inquiry of this kind related to the last pay week in October, 1950, and the information provided by 58,500 establishments, in respect of about 6,500,000 workpeople, has now been summarised by the Ministry. The wages shown in the returns represented the total earnings, inclusive of bonuses, before any deductions were made for income tax and contributions to the national insurance schemes.

The survey shows that, in the last pay week of October, 1950, the average earnings in all the industries covered by the inquiry were: men, £7 10s. 5d.; youths and boys, £3 3s. 9d.; women, £4 2s. 7d.; girls, £2 13s. 5d., and for all workers, £6 8s. Taking the manufacturing industries only, the figures were, respectively, £7 16s. 8d., £3 2s. 1d., £4 3s. 2d., £2 13s. 9d., and £6 7s. 5d. In the group of manufacturing industries classified as "engineering, shipbuilding and electrical goods," the average weekly earnings were shown as: men, £7 16s. 5d.; youths and boys, £2 16s. 11d.; women, £4 5s. 1d., and girls £2 12s. 8d. From the figures supplied, the Ministry has calculated that, in all the industries investigated, the percentage increases in wages between October, 1938, and October, 1950, were: men, 118; youths and boys, 144; women, 154, and girls, 189.

The average hours worked during the last pay week of October, 1950, in all the industries covered by the inquiry, were: men, 47·6; youths and boys, 44·4; women, 42, and girls, 42·6. In the "engineering, shipbuilding and electrical goods" group, the average hours were: men, 47·8; youths and boys, 43·9; women, 42·7; and girls, 42·5, giving an average of 46·7 hours for all workers in the group. The average hours worked in all industries in October, 1938, were: men, 47·7; youths and boys, 46·2; women, 43·5, and girls, 44·6.

It should be noted that among the employments excluded from the inquiry were agriculture, coal mining, railway and shipping services, and port transport.

Changes in Wage Rates

The Ministry of Labour has announced that changes in wage rates, reported as having come into operation in February, resulted in an aggregate increase of about £551,000 in the weekly full-time wages of 2,234,000 workpeople. Among the people affected by the increases were workers in the building industry, civil engineering construction, the railway service, the road vehicle retail and repairing trade, the port transport industry, and Admiralty dockyard establishments. Certain workers in the iron, steel and non-ferrous scrap industry and in the coal mining industry also received increases.

In the first two completed months of this year, changes in wage rates resulted in an aggregate increase of £1,117,500 in the weekly full-time wages of 4,089,000 workers. In the corresponding months of last year there was a net weekly increase of £289,500 in the wages of 1,848,500 workpeople. At the end of February, the index figure of rates of wages (June, 1947=100) was 116 for all workers. From March to September last year the index remained at 110. By the end of December last it had moved to 114, and has subsequently risen a further two points.

Trade Disputes

According to the *Ministry of Labour Gazette*, there were 119 stoppages of work which started in February through industrial disputes, and another nineteen stoppages, which had begun earlier, were in progress at some time during the month. The approximate number of workers involved in these 138 stoppages during February was 57,800, and it has been calculated that, in the aggregate, 340,000 working days were lost. In the first two months of this year, the Ministry reports, there were 249 stoppages of work through disputes, involving 76,700 workpeople and causing an aggregate loss of 418,000 working days. In the first two months of 1950 there were 238 stoppages reported, affecting 42,800 workpeople, and resulting in a loss of 156,000 working days.

Of the February stoppages, the coal mining industry accounted for seventy-six, involving 8300 workers and showing an aggregate loss of 20,000 working days. In the transport industry there were eight stoppages, which involved 34,100 workers and caused an aggregate loss of 211,000 working days. They included the dock strikes—mainly on Merseyside and Clydeside—staged as a protest against the national award which increased wages by 11s. a week. There were also unofficial stoppages on the railways over the recommendations made by the Court of Inquiry into wage claims.

Royal Ordnance Factories' Dispute

Rather more than a week ago, workers at Woolwich Arsenal and some other Royal Ordnance factories, expressed their intention to impose a ban on overtime as a protest against the Government's refusal to grant them two weeks' annual holiday with pay, instead of one as at present. The holiday claim was put forward some months ago by the trade union side of the joint co-ordinating committee for Government industrial establishments. The Government has already accepted the claim in principle but has pointed out that it cannot be granted in the present economic position. The workpeople's action is quite unofficial and on Tuesday last the Chancellor of the Exchequer stated that the claim for a second week's holiday with pay could not be discussed further while the overtime ban continued.

Notes and Memoranda

Rail and Road

LONDON TRANSPORT ENGINEER IN U.S.A.—Arising out of an offer by the Economic Co-operation Administration for an employee from the British transport industry to obtain experience of developments aimed at improving productivity in the American transport industry, Mr. J. G. Bruce, A.M.I.E.E., has been selected by the British Transport Commission to visit America for this purpose. Mr. Bruce, who is production engineer at London Transport's railway rolling stock overhaul works at Acton, has now left for the U.S.A., and will be away for approximately five months.

Air and Water

AUSTRALIAN AIRCRAFT RESEARCH.—Research work which has been proceeding for four years upon the Griffiths "GLAS II" (suction wing) at the Commonwealth Research Laboratories, Melbourne, has now been suspended. A preliminary design study had already been made on a swept all-wing aircraft of 70,000 lb weight, 100ft span and capable of carrying seventy passengers. It is thought that a higher priority has been given to boundary layer control problems with thin wings.

Miscellanea

ATOMIC ENERGY SCHOOL.—The Atomic Energy School, which has been set up at Harwell by the Ministry of Supply to teach industrial laboratory workers the use of radioactive materials, was opened on Monday, April 2nd, by Sir John Cockcroft, F.R.S., Director of the Atomic Energy Research Establishment.

INSTITUTION OF SANITARY ENGINEERS.—We have received from the Institution of Sanitary Engineers a copy of the 1950 edition of its "Particulars of Examinations," which contains several important revisions in the regulations and syllabus. It is now possible to take the Associate Membership examination one or two parts at a time.

COMMERCIAL CONDITIONS IN COSTA RICA.—The Board of Trade announces the publication, by H.M. Stationery Office, of a survey of economic and commercial conditions in Costa Rica. It is the latest volume in the series of overseas economic surveys issued by the Commercial Relations and Exports Department of the Board of Trade.

INSTITUTION OF WATER ENGINEERS.—The summer meeting of the Institution of Water Engineers will be held this year at Keswick, on Tuesday, Wednesday and Thursday, May 8th to 10th. The proceedings will include the Institution's general meeting, the presentation of several technical papers, and various visits in the neighbourhood, including one to the Haweswater dam.

BUILDING RESEARCH CONGRESS.—The organising committee of the Building Research Congress, to be held in London in September next, announces that it is now considering closing the membership list. More than 1000 delegates have already accepted invitations to attend. They include the directors of building research of ten Commonwealth and Continental countries and official representatives of many colonial and other countries.

SWEDEN'S IRON AND STEEL EXPORTS.—According to *The Anglo-Swedish Review*, Sweden's iron ore exports last year amounted to 12,900,000 tons, compared with 12,700,000 tons in 1949. Exports of iron and steel totalled 216,000 tons last year, as against 155,900 tons in 1949. It is stated that pig iron exports accounted for most of the increase. Ferrous alloys and sponge iron were also exported in larger quantities last year, the total amount being 22,100 tons, compared with only 8900 tons in 1948.

IRON FOUNDRY ADVISORY TEAM.—A specialist team has now been set up by the British Cast Iron Research Association, with the support of the Joint Iron Council, to visit iron foundries in the United Kingdom to study and report on their operating efficiency. The leader of the team is Mr. J. Hunter, who has had considerable experience in the design and equipment of foundries, and who has been for the last six years manager and chief designer of the foundry equipment division of Stone-Wallwork, Ltd. The reports of the team will be confidential to member-firms. The Association has also appointed Mr. W. D. Bamford, A.M.I.E.E., to advise foundries anxious to meet the requirements of the Garrett Report on heating and ventilation problems.

CONFERENCE ON PRESTRESSED CONCRETE.—A conference on prestressed concrete is to be held at the Massachusetts Institute of Technology, from August 14th to 16th, 1951. Applications of prestressed concrete, manufacture and construction, and problems in research will be discussed at the conference, the general emphasis being on design and construction practice in the United States and its relation to the practices already adopted in other countries.

SULPHURIC ACID PRICES.—The Board of Trade has made an Order, which will come into effect on April 9th, permitting increases in the maximum prices of sulphuric acid, owing mainly to the advances in the world prices of sulphur and pyrites and of freight rates. The additions to maximum prices are 26s. 6d. per ton on weak acid (77 per cent H_2SO_4) and 33s. 9d. per ton on strong acid (more than 84·02 per cent H_2SO_4). The Order is entitled the Sulphuric Acid (Prices) Order, 1951 (S.I. 1951, No. 551).

FIRST EUROPEAN MACHINE TOOL EXHIBITION.—We are informed by the organisers of the First European Machine Tool Exhibition, which is to be held in Paris from September 1st to September 10th next, that about 600 manufacturers from a number of different countries have already stated their intention to exhibit their products. Of the 45,000 square metres of exhibition halls available, some 18,000 square metres have been reserved to date by machine tool builders and 6000 square metres by manufacturers from allied trades. The organisers of the exhibition are the Syndicat des Constructeurs Français de Machines Outels, 2 bis, Rue de la Baume, Paris (8e).

FLOW PRODUCTION.—The College of Technology, Birmingham, is organising a series of six lecture-discussions for senior industrial executives on the subject of "Basic Principles of Flow Production." They will take place on Saturday mornings, beginning April 21st. The course is to be conducted by Mr. F. G. Woollard, M.I.Mech.E., M.I.Prod.E., M.S.A.E., who has built up a store of practical experience in the subject during many years in the automobile and allied industries. In the lectures Mr. Woollard will reduce to fundamental principles the general knowledge which has been accumulated on this subject and will explain how they can be applied more widely. The course aims to show how flow production methods can make a powerful contribution to productivity. Further particulars may be obtained from the Department of Industrial Administration, College of Technology, Birmingham.

ALUMINIUM ALLOY RIVETS.—Research report No. 8, entitled "Tests in the Production and Driving of Large Aluminium Alloy Rivets," has recently been published by the Aluminium Development Association. The report consists of six sections, three of which refer to rivet stock and rivets. The remaining three deal with driving and the properties of driven rivets. The results of the examination of rivet stock are given and include chemical composition, physical properties and macro and micro studies. This is followed by similar observations with reference to manufactured rivets. A section is devoted to the forming of several point shapes by hydraulic and pneumatic means, the hydraulic pressures are recorded and there is a note upon temperature effect. The marked effect of point shape upon closing behaviour is illustrated, special attention being paid to a recessed design. A table gives hardness values for a number of driven rivets and photographs show the macro structure, while the conclusions reached are surveyed in the final section. Appendices to the report discuss methods of obtaining pin-shear values, compression test procedures, Canadian experiments and French experience in driving large aluminium alloy rivets.

Launches and Trial Trips

HAUT-BRION, motor coaster; built by Chantiers et Ateliers Augustin Normand for le Ministère de la Marine Marchande; length b.p. 59·4m, breadth moulded 9·3m, depth moulded 4·4m, deadweight 850 tonnes; M.A.N., two-cycle single-acting diesel engine, 750 b.h.p., 180 r.p.m. Launch, March 22nd.

AUREOL, passenger liner; built by Alexander Stephen and Sons, Ltd., for the Elder Dempster Lines, Ltd.; length 538ft, breadth 70ft, depth 36ft 6in; two sets of Stephen-Doxford oil engines each having four cylinders, 670mm diameter by 2320mm combined stroke, total output 9400, b.h.p. at 118 r.p.m. Launch, March 28th.

Personal and Business

MR. R. E. DYMOND has been appointed technical director of Electropower Gears, Ltd., Kingsbury Road, London, N.W.9.

CLARKSON (ENGINEERS), Ltd., states that it has now started to build an extension to its works in King Edward Road, Nuneaton.

DUCTUBE COMPANY, Ltd., announces that its address is now Regent House, 235–241, Regent Street, London, W.1 (telephone, Regent 2502).

THE BRITISH THOMSON-HOUSTON COMPANY, Ltd., states that its Swansea district office is now designated as 12–13, The Kingsway, Swansea (telephone, Swansea 2151).

SHELL-MEX AND B.P., Ltd., announces the retirement of its managing director, Mr. C. M. Merrick, who joined the company in 1924. Mr. C. M. Vignoles succeeds him as managing director.

MR. J. T. FIRTH, B.Eng., M.I.C.E., formerly engineer to the Mersey and Irwell Catchment Board, has now taken up his appointment as chief engineer to the newly formed Mersey River Board.

FERODO, LTD., states that its Leeds branch has been transferred to Ferodo House, 80, North Street, Leeds, 2. The Aberdeen depot is to move on April 17th to Ferodo House, 27–29, Virginia Street, Aberdeen.

DR. E. C. ROLLASON has been appointed Professor of Metallurgy at Liverpool University and will relinquish his present post of director and research manager at Murex Welding Processes, Ltd., Waltham Cross, on September 28th.

G. E. SIMM (MACHINERY), Ltd., East Parade, Sheffield, 1, has been appointed sole sales representative for the Holset range of couplings, gears and torsional vibration dampers manufactured by W. C. Holmes and Co., Ltd., Huddersfield.

JACK OLDING AND CO., Ltd., Hatfield, Herts., announces a reorganisation by which it has been converted into a holding company, known as Oldings (Hatfield), Ltd. Its operating business is to be transferred to a subsidiary company, which will trade under the name Jack Olding and Co., Ltd.

MR. G. R. MORGAN, A.M.I.E.E., and Mr. E. D. Holdup, A.M.I.Mech.E., A.M.I.E.E., of the South-Eastern Division, British Electricity Authority, are taking up new appointments with the Hydro-Electric Power Commission of Ontario. Mr. Morgan will be responsible for the administration of all steam plant belonging to the Commission and Mr. Holdup is to become superintendent of the new J. Clark Keith power station at Ontario.

Contracts

HALL, RUSSELL AND CO., Ltd., has contracted to build and engine a cargo vessel of 2500 tons deadweight and 12½ knots speed for A/S Borgs. The propelling machinery will consist of a Fredrikstad steam motor of 1320 s.h.p.

JOHN I. THORNYCROFT AND CO., Ltd., has received a contract from the South African Railways, through Robertson and Moss, Ltd., its local distributors, for heavy-duty, three-axled chassis to the value of over £500,000. The majority of these chassis will be powered by Thornycroft 170 b.h.p. petrol engines and the remainder by Thornycroft diesel engines.

SULZER BROS. (LONDON), Ltd., has received from the Algerian Railways an order for ten diesel-electric locomotives, each powered by a Sulzer engine of 1070 h.p. (derated to 960 b.h.p. on site), for operating the heaviest freight and passenger traffic on the Blida-Djelfa line of 1055mm gauge. The estimated weight of each locomotive is 72 tons and the top speed is limited to 53 m.p.h.

FOR the extension of the Waitaki power station of the New Zealand Hydro-Electric Department, a contract for supplying six 5·5MVA single-phase, water-cooled transformers has been awarded to the British Electric Transformer Company, Ltd. The transformers will form two three-phase 16·5 MVA banks, each stepping-up the 11kV output from a 15MW generator to 110kV for transmission.

THE BLYTHSWOOD SHIPBUILDING COMPANY, Ltd., has received an order from the Baltic Trading Company, Ltd., for an oil tanker of 20,000 tons deadweight and 15½ knots speed, fully loaded, and powered by a single set of double-reduction geared turbines. Another tanker ordered from the company is of 3500 tons deadweight for Skibsaktieselskapet William Hansens Rederi, and will be fitted with triple-expansion machinery to give a speed of 11 knots. David Rowan and Co., Ltd. will supply the machinery for both vessels.

British Patent Specifications

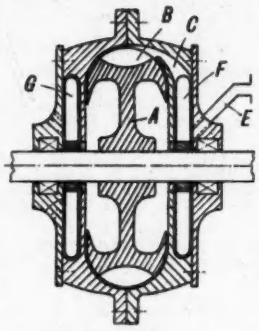
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

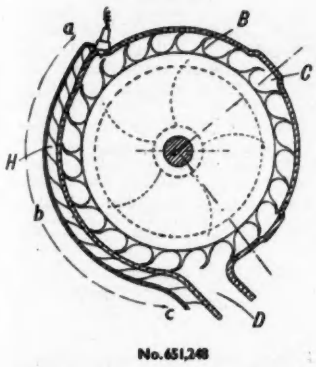
Copies of specifications may be obtained at the Patent Office Sale Branch, 25, Southampton Buildings, Chancery Lane, W.C.2, 2s. each.

INTERNAL COMBUSTION ENGINES

651,248. December 29, 1948.—Improvements in or relating to Internal Combustion Engines, Francois Waloszek, a French citizen, of Route d'Hénin-Lietard, Beaumont en Artois (Pas-de-Calais), France.

The engine according to the invention comprises a turbine fixed on the driving shaft between two fans, one of which is adapted to act as a compressor for the gaseous mixture received from the carburettor, and the other of which is used for cooling the explosion chamber. The turbine *A* comprises peripheral blades *B* of curved cross-sectional shape having the end flattened so as to provide the necessary fluid-tight contact with the casing. The





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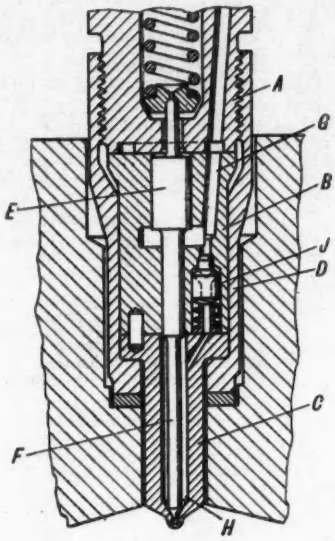
inlet chamber is shown at *C* and the exhaust pipe at *D*. The explosive mixture is fed through the pipe *E* and the gases are compressed and forced into the inlet chamber by the fan *F*, which is fixed on the driving shaft. Another fan *G* on the opposite side of the turbine sucks in the outside air and forces it through the annular space *H*, in which helical grooves keep the air in contact with the wall of the combustion chamber and cool it. Ignition by means of a sparking plug is only necessary when starting. As soon as the normal speed has been reached, self-combustion is produced in the chamber *a–b–c* and the ignition may be cut off.—*March* 14, 1951.

651,158. June 15, 1948.—Improvements in or relating to Fuel-Injection Nozzles for Internal Combustion Engines, Aktiebolaget Atlas Diesel, Sickla, near Stockholm, Sweden.

One object of the invention is to produce a fuel-injection nozzle with small diameter so that it can be disposed in a narrow space in an engine, and a nozzle in which the portion directly exposed to the combustion heat may be changed. The nozzle comprises a valve housing assembly formed by three separate parts *A*, *B* and *C*, held together by a nut *D* and assembled as a unit into a wall of a combustion chamber. A main valve member is movable in the valve housing assembly in conventional manner under the action of the fuel pressure. The valve member comprises a plunger *E* with a portion of smaller diameter and a stem *F*. The upper plunger portions are guided in corresponding bores in the valve housing, in which they form fluid-tight seals. The stem extends freely into the tip of the valve housing assembly and forms the means which shuts off a fuel passage *G*, *H* to the nozzle openings in the valve housing assembly and co-operates with a valve seat formed close to the nozzle openings in the tip *C*. The valve member is loaded in conventional manner by a pressure spring acting to close the valve member against the fuel pressure. An auxiliary non-return



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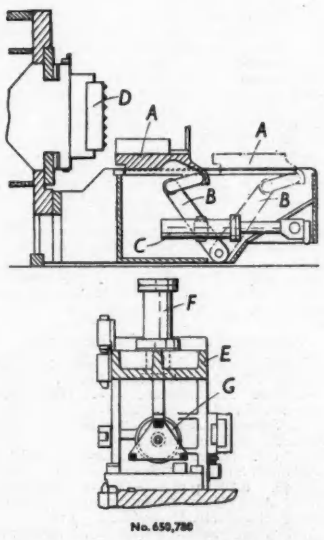
valve *J* is provided in the part *B* of the valve housing encircling the small diameter bore. The auxiliary valve can be provided with a pressure-reducing portion which may co-operate with a stopper for limiting the valve motion.—*March* 14, 1951.

MACHINE TOOLS

650,780. July 9, 1947.—Broaching Machines, Vincent Allen Skinner and Weatherley Oilgear, Ltd., both of the company's address, Biggleswade, Bedfordshire.

This invention provides improved loading, clamping and unloading apparatus for components to be machine broached. The particular version described is applicable to horizontal surface broaching machines. Supported in brackets from the main machine frame are guides for a sliding table *A*. The table, which is driven by link gear *B* by the cylinder *C* of an hydraulic ram, moves in and out in a plane transverse to the line of movement of the broaching tool holder *D*. The upper



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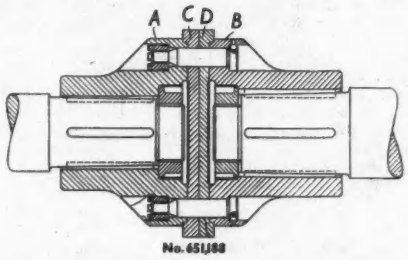
surface of the table may be shaped to receive a particular component where production requirements justify this or may carry adjustable pads or jigs to make it adaptable. A relatively massive cradle *E* forming part of (or fixed to) the main frame of the machine is arranged to receive workpieces from the table as it comes to the limit of its inward movement (shown in full lines in the drawing). The cradle is fitted with one or more hydraulic clamps *F*, *G*, which preferably hold the workpiece against a solid abutment so that the stress set up by the broaching operation is transmitted straight back to the machine frame through a bracket. In this kind of hydraulic clamping the clamping forces and the forces applied to back up wedges behind relatively weak sections of a component being broached can be accurately preset and controlled despite inconsistencies in component thicknesses, thus ensuring uniformity of accuracy in the finished component.—*March* 7, 1951.

POWER TRANSMISSION

651,188. October 26, 1949.—Improvements in and relating to Shaft Couplings, Aktiengesellschaft für Technische Studien, of Hardstrasse, 319, Zürich, Switzerland.

The invention relates to a shaft coupling comprising flanges keyed on the shafts to be connected; it is suitable more especially for coupling high-speed shafts subjected to the action of considerable axial tensile forces and for transmitting high power. On the slightly tapered ends of two shafts to be coupled are keyed coupling flanges *A* and *B*. Two centring discs *C* and *D* are inserted between the faces of the coupling flanges. The centring discs are each provided on the outside with an annular shoulder, against which the opposite ends of the coupling flanges are rigidly assembled by reamed bolts. The bolt heads are prevented



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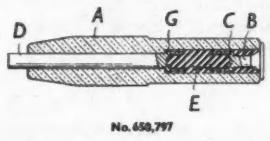
from turning by pins and the castellated nuts have cylindrical portions which fit holes formed in the flanges. In this way the nuts are prevented from taking up an oblique position under the action of the centrifugal forces, so that the bolts are not subjected to any substantial bending stresses. This fact materially contributes to operational safety and to the maintenance of the various parts of the coupling in the necessary positions. The same applies to the annular shoulders against which the ends of the flanges bear and which, due to the rigidity of the centring discs, prevent parting of the ends under the influence of the centrifugal forces. The shaft coupling described is suitable more especially for use in cases where the engines whose shafts are to be coupled only permit a small displacement in the axial direction, since axial displacement of one of the shafts by a little more than the width of one of the shoulders is sufficient to enable the centring discs to be removed.—*March* 14, 1951.

MISCELLANEOUS

650,797. August 18, 1947.—Spark Plug Construction, Bendix Aviation Corporation, 401, Bendix Drive, South Bend, Indiana, United States of America.

This invention relates to spark plug construction and particularly concerns an improved centre electrode assembly. The centre electrode assembly comprises a tubular insulator *A* and a terminal member *B* having a head and a socketed end *C*, which is smaller than the upper part of the bore of the insulator. The head of the terminal member extends over the end of the insulator and is adapted to assist in sealing its contents. The insulator is provided with an internal shoulder at the boundary between the



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larger part of the bore and the smaller part. A centre electrode sparking element *D* fits the lower end of the bore and has a socketed end with a shoulder that is adapted to rest upon the insulator shoulder and to aid in sealing that portion of the assembly. The sockets of the terminal element and the sparking element open toward each other and are adapted to receive in their ends a connector *E* of resilient material having hooked ends and a mid section bent or curved to provide resilience and expansibility. In assembling the connector is seated in the socket *G*. The space about and within the socketed end of the sparking element and the bore of the insulator is filled with a mixture of lead oxide and boro-silicate glass, all preferably in powdered form. The socket in the terminal element is forced over the hooked end of the wire and a firm contact is established by the compression of the

hook as it is forced into the spindle. The curved midsection of the spring permits it to be compressed sufficiently to ensure proper seating of the parts. The sockets have conical ends which provide the curve of the hook with four places of contact, two upon the sides of the socket and two against the sides of the cone. The insulator is heated in the region of the boro-silicate fill until it becomes plastic, while maintaining sufficient pressure upon the terminal to keep the spring in a bent position until the glass has solidified.—*March 7, 1951.*

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

Association of Supervising Electrical Engineers

To-day, April 6th.—LIVERPOOL BRANCH: Electricity Showrooms, Whitechapel, Liverpool, "Methods of Assessing and Charging for Electrical Energy," B. R. Campbell-Kelly, 7 p.m.

Tues., April 10th.—BOLTON BRANCH: York Cafe, Great Moor Street, Bolton, "Distribution," J. Yates, 7.15 p.m.

Fri., April 13th.—CREWE BRANCH: Crewe Arms Hotel, Crewe, "Battery Vehicles," R. D. Morgan, 7.30 p.m.

British Institution of Radio Engineers

Wed., April 11th.—S. MIDLANDS SECTION: Public Library, Graham Road, Malvern, "The Germanium Triode," E. G. James, 7.15 p.m.——N.W. SECTION: College of Technology, Manchester, "Frequency Modulation and F.M. Measuring Equipment," E. D. Hart and A. G. Wray, 7.15 p.m.——N.E. SECTION: Neville Hall, Westgate Road, Newcastle upon Tyne, "The Elements of Pulse Code Modulation," S. R. Rickman, 6 p.m.

British Interplanetary Society

Sat., April 7th.—Caxton Hall, Caxton Street, London, S.W.1, "The Evolution of Life in The Universe," J. D. Bernal, 6 p.m.

Illuminating Engineering Society

To-day, April 6th.—BATH AND BRISTOL CENTRE: Grand Hotel, Bristol, Presidential Address, L. J. Davies, 7 p.m.——HUDDERSFIELD GROUP: Electricity Showrooms, Market Street, Huddersfield, "Safety and Vision," E. W. Murray, 7.15 p.m.

Tues., April 10th.—Lighting Service Bureau, 2, Savoy Hill, London, W.C.2, "Recent Developments in Gas Street Lighting," P. Crawford, 6 p.m.——STOKE-ON-TRENT GROUP: 31, Kingsway, Stoke-on-Trent, "Lighting in the Pottery Industry," H. Wade Harvey, 6 p.m.

Thurs., April 12th.—College of Technology, Manchester, Annual General Meeting, "Home Lighting," J. N. Aldington, 6 p.m.

Incorporated Plant Engineers

Mon., April 9th.—DUNDEE BRANCH: Mathers Hotel, Dundee, "Metallizing for Industrial Plant Maintenance," J. Barrington Stiles, 7.30 p.m.

Wed., April 11th.—E. MIDLANDS BRANCH: Welbeck Hotel, Nottingham, "An English Oilfield," C. M. Adcock, 7 p.m.

Thurs., April 12th.—KENT BRANCH: Technical College, Maidstone, "Power and Process Heat Balance," Oliver Lyle, 7 p.m.——NEWCASTLE UPON TYNE BRANCH: Royal Turks Head Hotel, Grey Street, Newcastle upon Tyne, "Welding and Equipment," 7.30 p.m.

Institute of British Foundrymen

Sat., April 7th.—LANCASHIRE BRANCH: Engineers' Club, Albert Square, Manchester, Annual General Meeting, 2.45 p.m.

Thurs., April 12th.—LINCOLNSHIRE BRANCH: Technical College, Lincoln, General Meeting, Short Paper Competition, 7.15 p.m.

Institute of Economic Engineering

Sat., April 7th.—Christian Institute, Glasgow, "Anglo-American Productivity," Jas. Jackson, 10.30 a.m.

Institute of Industrial Administration

Thurs., April 12th.—School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1, Annual General Meeting, "Does Management Make the Best Use of the Facilities Available," Lord Verulam, 7 p.m.

Institute of Industrial Supervisors

Tues., April 10th.—DUDLEY AND DISTRICT SECTION: Technical College, Dudley, "Public Parks and Recreation Grounds—Their Relation to Industry," F. A. Boddy, 7.30 p.m.——KIDDERMINSTER SECTION: Carpet Trades, Ltd., Mill Street, Kidderminster, "Accident Causes and Prevention," E. H. Hudson, 7.30 p.m.

Wed., April 11th.—W. BROMWICH SECTION: Grammar School, West Bromwich, "Joint Consultation and the Foreman," J. A. Hunt, 7.45 p.m.

Institute of Marine Engineers

Tues., April 10th.—85/88, The Minories, London, E.C.3, "Electrical Machinery in a Cargo Liner," J. B. Peacock, 5.30 p.m.

Institute of Petroleum

Wed., April 11th.—26, Portland Place, London, W.1, "I.P. Standardisation," Symposium, 5.30 p.m.

Institute of Physics

Thurs. and Fri., April 12th and 13th.—Ashorne Hill, Leamington Spa, X-Ray Analysis Group, Spring Conference, "The Texture and Structure of Metals."

Institute of Road Transport Engineers

Mon., April 9th.—SCOTTISH CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "The Use of Lightweight Sandwich Materials in the Construction of Road Transport Vehicles," F. C. Lynam, 7.30 p.m.

Tues., April 10th.—E. MIDLANDS CENTRE: Engineers' Institute, Nottingham, "The Care and Maintenance of Sparking Plugs," 7.30 p.m.

Fri., April 13th.—S. WALES GROUP: Institute of Engineers, Park Place, Cardiff, Open Discussion Meeting, 7 p.m.

Institution of Chemical Engineers

Wed. to Sun., April 11th to 15th.—Nutford House, Brown Street, London, W.1, 1951 Convention, "Chemical Engineering—Opportunities in Specific Industries."

Institution of Civil Engineers

Tues., April 10th.—Great George Street, Westminster, S.W.1, "Civil Engineering and Medicine in the Field of Environmental Health," N. R. Beattie, 5.30 p.m.

Thurs., April 12th.—MIDLANDS ASSOCIATION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Aluminium as a Structural Material," E. Longbottom, 6 p.m.——N. W. ASSOCIATION: Engineers' Club, Albert Square, Manchester, "Underground Work in Compressed Air," P. Murray, 6.30 p.m.

Institution of Electrical Engineers

Sat., April 7th.—N. MIDLAND STUDENTS' SECTION: Yorkshire Electricity Board Offices, Market Street, Huddersfield, "The Domestic Radio Receiver," B. S. Dilnot, 2.30 p.m.

Mon., April 9th.—LONDON STUDENTS' SECTION: Savoy Place, Victoria Embankment, W.C.2, "CO_2 Equipments," D. W. Foster and W. E. M. Arundel, 7 p.m.——N.E. CENTRE: Royal Station Hotel, Newcastle upon Tyne, Annual General Meeting and Conversazione, 6.15 p.m.

Wed., April 11th.—Savoy Place, Victoria Embankment, W.C.2, "A V.H.F. Field-Strength Survey on 90 Mc/s," H. L. Kirke, R. A. Rowden and G. I. Ross; "The Propagation of Metre Radio Waves Beyond the Normal Horizon," J. A. Saxton, G. W. Luscombe and G. H. Bazzard, 5.30 p.m.

Thurs., April 12th.—UTILISATION SECTION: Savoy Place, Victoria Embankment, W.C.2, "Modern Developments in Electric Welding," H. G. Taylor, 5.30 p.m.

Fri., April 13th.—Savoy Place, Victoria Embankment, W.C.2, Discussion on "The Presentation of Laboratory Experiments," opened by G. F. Freeman, 6 p.m.

Institution of Heating and Ventilating Engineers

Tues., April 10th.—S.W. BRANCH: R.W.A. School of Architecture, Bristol, Annual General Meeting, followed by a Short Paper and Discussion, 6.30 p.m.

Wed., April 11th.—LONDON AND DISTRICT ASSOCIATE MEMBERS AND GRADUATES SECTION: 178/180, Edgware Road, W.2, "Fire Fighting Equipment in Buildings," H. Hoyle, 6.30 p.m.

Institution of Mechanical Engineers

To-day, April 6th.—Storey's Gate, St. James's Park, S.W.1, "Load Distribution in Riveted and Spot-Welded Joints," D. Williams, "Design Stresses in Fillet Weld Connections," F. Koenigsberger, 5.30 p.m.

Sat., April 7th.—N.E. BRANCH, GRADUATES' SECTION: Northern Gas Board Showrooms, Grainger Street, Newcastle upon Tyne, Annual Film Show, 2.30 p.m.—YORKSHIRE BRANCH, GRADUATES' SECTION: Great Northern Victoria Hotel, Bradford, "Selection of Personnel for the Engineering Industry," H. Bailey, 2.30 p.m.

Tues., April 10th.—AUTOMOBILE DIVISION: Storey's Gate, St. James's Park, S.W.1, "The Development of the De Havilland Series of Engines for Light Aircraft," J. L. P. Brodie, 5.30 p.m.

Thurs., April 12th.—WESTERN A.D. CENTRE: Park Hotel, Cardiff, "Some Factors Governing the Performance of Crankcase Lubricating Oils," A. Towle, 6.45 p.m.

Fri., April 13th.—Storey's Gate, St. James's Park, S.W.1, "Steam Piping for High Pressures and High Temperatures," R. W. Bailey, 5.30 p.m.

Institution of Production Engineers

To-day, April 6th.—LUTON GRADUATE SECTION: Library Lecture Hall, Williamson Street, Luton, "Spinning a Yarn—Cotton Manufacture," J. Horridge, 7.30 p.m.——COVENTRY GRADUATE SECTION: Geisha Cafe, Hertford Street, Coventry, "Plastic Materials in Production," A. Beecham, 7.15 p.m.

Mon., April 9th.—SHEFFIELD SECTION: Royal Victoria Station Hotel, Sheffield, "Modern Marking Methods," A. Throp, 6.30 p.m.——DERBY SUB-SECTION: School of Art, Green Lane, Derby, "Rubber and Allied Materials," Mr. Reynolds, 7 p.m.

Tues., April 10th.—BIRMINGHAM GRADUATE SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Defects and Developments in Deep Drawing and Pressing," J. D. Jevons, 7 p.m.——DUNDEE SECTION: Mathers Hotel, Whitehall Crescent, Dundee, "Starting a New Factory," A. R. Northover, 7.30 p.m.

Wed., April 11th.—LIVERPOOL SECTION: Exchange Hotel, Tithebarn Street, Liverpool, Annual General Meeting, 7.15 p.m.

Thurs., April 12th.—ROCHESTER AND DISTRICT SUB-SECTION: Sun Hotel, High Street, Chatham, "Production of Automobile Gears," T. Vickerman, 7.30 p.m.——SOUTHERN SECTION: Polygon Hotel, Southampton, "The Use of Rubber as an Engineering Material," G. W. Trobridge, 7 p.m.——WOLVERHAMPTON GRADUATE SECTION: Star and Garter Hotel, Wolverhampton, "Press Tools," J. A. Grainger, 7.30 p.m.

Institution of Sanitary Engineers

Tues., April 10th.—Caxton Hall, Westminster, S.W.1, "Sanitation in Multi-Storey Buildings," H. E. Gooding, 6.30 p.m.

Institution of Structural Engineers

To-day, April 6th.—WESTERN COUNTIES BRANCH: Grand Hotel, Bristol, Annual General Meeting, 6.15 p.m.

Thurs., April 12th.—11, Upper Belgrave Street, London, S.W.1, "The Design and Construction of a Large Span Prestressed Concrete Shell Roof," G. W. Kirkland and A. Goldstein, 5.55 p.m.

Institution of Works Managers

Tues., April 10th.—W. MIDLAND BRANCH: Grand Hotel, Birmingham, "The Value of Statistical Methods of Control," P. Lyle, 7 p.m.

Thurs., April 12th.—WEMBLEY SUB-BRANCH: The Plough, Kenton Road, Kenton, "The Economics of Management in a Small Factory," R. A. Burgoyne, 12.30 p.m.——TEES-SIDE BRANCH: Vane Arms Hotel, Stockton, Annual General Meeting, 7.30 p.m.

Fri., April 13th.—MANCHESTER BRANCH: Grand Hotel, Manchester, Annual General Meeting, 7 p.m.

Fri. to Sun., April 13th to 15th.—Prince of Wales Hotel, Southport, National Conference, "Works Managers and the Present Economic Situation."

Junior Institution of Engineers

To-day, April 6th.—39, Victoria Street, S.W.1, Films, "Precision Machine Tools," "Metallic Bearing Surfaces," S. G. Jennings and F. Baxter, 6.30 p.m.

Fri., April 13th.—39, Victoria Street, London, S.W.1, "The Use of Models in Industry, Education, Invention and Recreation," R. H. Fuller, 6.30 p.m.

Manchester Geological and Mining Society

Thurs., April 12th.—Mining and Technical College, Wigan, "Further Reconstruction at Maypole Colliery," F. Edmond and J. Bennett, 3.15 p.m.

Newcomen Society

Wed., April 11th.—Science Museum, South Kensington, S.W.7, "Some Notes on Dutch Watermills," E. M. Gardner, "Three Types of Windmills in Southern Brittany," G. Huard, Rex Wailes and H. A. Webster, 5.30 p.m.

North East Coast Institution of Engineers and Shipbuilders

Fri., April 13th.—Neville Hall, Westgate Road, Newcastle upon Tyne, "The Improvement of Environmental Conditions in Ships' Machinery Spaces," Margaret Fishenden and S. A. M. Davidson, 6.15 p.m.

Old Centralians

Fri., April 13th.—Chez Auguste Restaurant, Frith Street, W.1, "The Future of Television—Here and Overseas," C. I. Orr-Ewing, 12.55 p.m.

Royal Aeronautical Society

Thurs., April 12th.—Institution of Civil Engineers, Great George Street, S.W.1, "Planning and Production Methods as Applied to the Comet," H. Povey, 6 p.m.

Stephenson Locomotive Society

Sat., April 7th.—32, Russell Road, Kensington, W.14, Annual General Meeting, 3.30 p.m.

Stoke-on-Trent Association of Engineers

Wed., April 11th.—Midlands Electricity Board, Back Glebe Street, Stoke, "Photography Applied to Engineering," A. Swindells, 7 p.m.

Women's Engineering Society

Thurs., April 12th.—35, Grosvenor Place, London, S.W.1, "London's Water Supply," F. Tattersall, 7 p.m.

Books of Reference

The Practical Engineer Pocket Book, 1951. Edited by N. P. W. Moore, B.Sc., A.C.G.I. London: Sir Isaac Pitman and Sons, Ltd., Parker Street, W.C.2. Price 8s. 6d. net.—The new edition of this useful little reference book has been completely reset and the contents rearranged. The section on internal combustion engines has been extended and a brief section added on the supercharging of engines. A new section on gas turbines gives historical notes and describes some typical cycles, materials for gas turbine construction and fuels. The basic data on the proposed unified standard screw threads given in the book are stated to be provisional and will be extended when the specifications are standardised.

The Directory of Shipowners, Shipbuilders and Marine Engineers, 1951. 49th edition. London: Tothill Press, Ltd., 33, Tothill Street, Westminster, S.W.1. Price 30s. net.—The forty-ninth edition of the "Directory of Shipowners, Shipbuilders and Marine Engineers" has been published recently and provides in convenient form particulars of the world's leading shipowning and shipbuilding companies, including additional information concerning Germany, Italy and Japan. The directory follows the pattern of previous years and the first section lists shipowners and gives details of their fleets, while the second section includes particulars of shipyards and marine engineering works. In both sections the names of the directors and executives of the various companies are recorded. Consulting naval architects and marine engineers are listed, also trade and technical organisations, classification societies and an official appendix is devoted to Government departments. Comprehensive indexes complete the volume and they include ship's names, companies in order of countries and towns, telegraphic addresses, a general index and a personal index.